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REVIEW DRAFT

BLM GUIDELINES

for

PRAIRIE/PLAINS

PLANT COMMUNITIES

to

INCORPORATE FIRE USE/MANAGEMENT

into

ACTIVITY PLANS

and

FIRE USE PLANS

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CREDITS

The efforts of a great many people went into these guidelines.

First and foremost is the Fire in Multiple Use Management RD&A program at the Northern Forest Fire Laboratory at Missoula. This cooperative effort between the Bureau of Land Management and the Forest Service is the moving force which makes these guidelines possible. RD&A contracted and paid for the literature searches which resulted in Chapters V, VII, and VIII.

Dr. Henry Wright of Texas Tech University researched and wrote the state-of-the-art paper on prescribed fire in the plains and prairies. He also furnished the burning prescription guides.

Dr. Wright and Rita Thompson of the RD&A program furnished the chapter on fire effects.

A portion of the format and information found in Chapters I & II was obtained from "A Guide for Prescribed Fire in Southern Forests" (Robley et al, 1973).

Chapter III, Smoke Management, is taken from a presentation made at Boise by Lester P. Mallory, Fire Weather and Air Pollution Service, NOAA.

The fire use plan chapter was taken from a paper by William C. Fischer, PLANNING FIRE USE: A Fire Management Approach, USDA Forest Service General Technical Report.

Information, both formal and informal, was obtained from the scientists at the Northern Forest Fire Laboratory, Missoula.

Some twenty people experienced in the fine art of prescribed burning assisted as instructors at the Prairie Workshop in Jamestown, North Dakota, April 25-28, 1978.

Before these guidelines become finalized, they will be tested by the Miles City, Montana BLM district by planning and executing a prescribed burn. After the test they will be revised as necessary and then distributed to the other BLM districts in the plains area.

INTRODUCTION

Past research and practice have shown that, under the proper conditions, fire can be an effective tool in resource management. Recent research has made a start at more precisely defining the proper conditions and more accurately quantifying results or impacts.

The change from fire control to fire management is one which must be done carefully and with detailed planning. With good planning and carefully written prescriptions, the manager can recognize situations where fire may have a potential for meeting management objectives and provide administrative necessities required to take advantage of favorable situations. HOWEVER, after a fire starts, it is a little late to plan and decide what should be done--you really have little choice but to put out the fire.

The BLM planning system is being revised to more adequately reflect fire management considerations in the planning process. URA and MFP procedures will be revised in FY 1977 and FY 1978. These guidelines presume that an MFP has been completed on the area and will concentrate on the activity and project plan levels. The guidelines also presume that the MFP has not laid down hard and fast constraints against the use of fire on the area to be planned.

Chapter I

BACKGROUND

Reasons for Prescribed Fire in Resource Management

There are a number of reasons for using prescribed fire in resource management. The following is a general discussion of those reasons. Specifics will depend on activity plan objectives.

Reduce Hazardous Fuels--

Prescribed fire is the most practical management tool to use where combustible fuels accumulate. Wildfires that burn into areas where fuels have been reduced by prescribed burning cause less damage. Prescribed burning for fuel reduction has no set time interval. However, degree of fire occurrence, risk, and fuel buildup will serve as guides in determining burning intervals.

When prescribed burning to reduce hazardous fuels, the objective is to break up the fuel continuity. Fuel reduction on 75-80% of the area should accomplish this.

Prepare Sites for Seeding--

Prescribed burning is useful in preparing a seedbed for herbaceous species where brushfields or solid stands of juniper now exist. It will expose mineral soil, reduce competition, and reduce or eliminate obstacles to seeding equipment.

Improve Wildlife Habitat--

Beneficial results from burning may include increase in yield and quality of herbage (particularly forbs) and browse, and creation of openings for feeding, travel, and dusting. One can also produce habitat which is optimum for a given wildlife species. This can be done by interrupting the process of plant succession to produce the seral stage most favorable to a particular species of wildlife. However, special care should be taken not to destroy critical areas such as large units of unburned brush for cover for big game or key cover for upland game birds.

Proper size, frequency, and time of burns are critical to success in the use of fire in managing wildlife habitat. Prescriptions should recognize the biological requirements of the preferred wildlife species as well as the vegetative conditions of the area.

Reduce Density and Cover of Brush

With improper grazing and protection from fire many stands of undesirable brush and trees have gradually gotten thicker and taken up space that was once occupied by grasses, forbs, and desirable shrubs. In many cases fire can be used to reverse this trend.

Improve Forage Quality, Accessibility, and Yields--

Vegetative manipulation by prescribed burning coupled with intensive livestock management can greatly enhance livestock forage. A properly burned area can realize a reduction of the less palatable plants and a rather dramatic increase of the more desirable species. Also, in areas of dense brush, the

stand can be opened making travel for livestock, especially sheep, much easier. Scrubs out of reach for livestock and game can become easily accessible with resprouts after a burn.

The point must be made that proper management of livestock is critical to achieving desired results following a burn, for without it, the area will soon return to its original condition.

Enhance Appearance--

Under some circumstances, prescription burning can be used for recreation and esthetic purposes to maintain parklike stands (trees), emphasize vegetative type changes, increase numbers and visibility of flowering annuals and biennials, and maintain open spaces. A diversity of vegetative types attracts a wider variety of bird and mammal species and makes them more visible.

There is great potential for the use of fire in managing the landscape and enhancing scenic values, and areas so treated have high public exposure.

Improve Watersheds--

Conversion from brush to grass can be effective in reducing flash runoff, increasing percolation, opening springs, and increasing groundwater supply.

Fire Effects

Environmental Effects--

Prescribed burning has direct and indirect effects on the environment. To properly prescribe and then evaluate both benefits and damages of a burn, it is necessary to know how fire affects vegetation, soil, water, air, and wildlife. Timing of burns and burning techniques may be used to obtain a wide range of fire effects.

Effects on Vegetation--

Prescribed fire may injure or kill only part of a plant or the entire plant, depending on how intense the fire burns and how long the plant is exposed to heat. In addition, the plant may have features that protect it from heat (bark on trees, growth form of grasses, etc.). Burning after recent rains will help protect susceptible bunchgrasses and shrubs from fire damage. When plants are actively growing they are more easily damaged by prescribed fire. The least fire damage occurs during a plant's dormant season.

Effects on Soil--

Specific effects on soil vary greatly. Frequency, duration and intensity of fire, and soil characteristics must all be considered. Prescribed burning normally causes little or no detectable change in amount of organic matter in surface soils. Typical prescribed fire temperatures will not cause changes in properties of mineral soil particles, but burning windrows of pinyon-juniper or high-intensity wildfires may produce enough heat to cause losses of soil organic matter and changes in the structure of soil clays.

front passes over an area, the temperature drop is usually accompanied by a drop in humidity. The lower humidity is the result of a change in airmass from warm and moist to cold and dry.

The moisture content of fine fuel responds rapidly to changes in relative humidity. However, because there is a timelag involved for heavier fuels to achieve equilibrium with the moisture condition of the surrounding atmosphere, and because previous drying or wetting regimes can influence fuel moisture, relative humidities by themselves cannot be relied upon completely for predicting the success or failure of a burn.

Rainfall--

Rainfall affects fuel moisture and soil moisture. In winter, rain or snow may be fairly easy to forecast, but in summer, when shower activity prevails, the prediction of rainfall at individual locations becomes very difficult. For this reason, the prescribed burner needs some idea of amounts of rain falling on the area to be burned. For range burning, however, the most important factor is to burn when the soil is moist and to wait for 4 or 5 days after a major storm before burning woody fuels.

Fine Fuel Moisture--

Fine fuel moisture is not a weather element but is influenced by relative humidity, rainfall, and temperature.

Relative humidity can control moisture content of fuels up to about 35%. Liquid moisture in the form of rain, snow, or dew must contact the fuel for moisture to go above 35%. The increase depends on duration as well as amount of precipitation. For example, 1 inch of rain occurring in 2 hours will not produce as large a moisture gain as 1 inch falling over a 12-hour period. Different types of fuels may reach different moisture content levels under the same humidity conditions. At 50 percent relative humidity, some grasses may contain 8% moisture, some brush leaves may have a moisture content as high as 10-14%. Because of these natural variations, any moisture values recommended are only guidelines. On-the-ground knowledge of fuels must be incorporated into planning the prescribed burn.

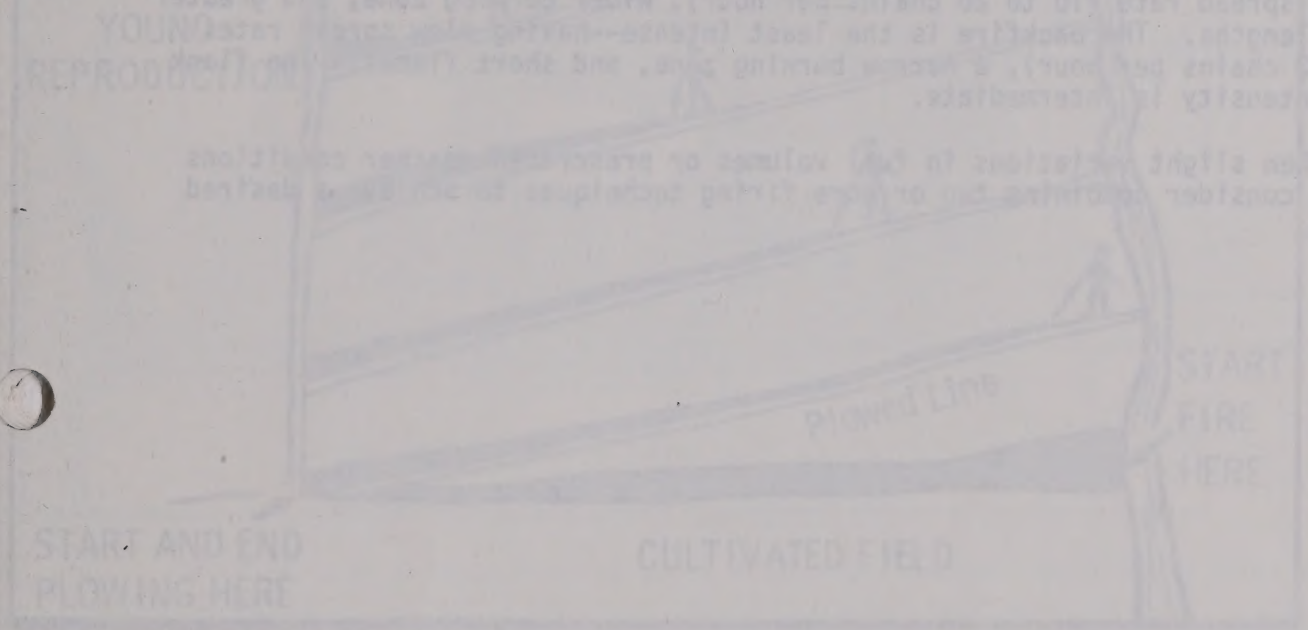
Airmass Stability--

Atmospheric stability is the resistance of the atmosphere to vertical motion. A prescribed fire generates vertical motion by heating the air, but the strength of convective activity over a fire is affected by the stability of the airmass. Strong convective activity will increase the indrafts into the fire and may result in erratic fire behavior, but give good dispersal of smoke.

When the atmosphere is stable, a small decrease in temperature occurs with an increase in altitude. Under very stable conditions, inversions may develop in which temperature actually increases with height. Stable air tends to restrict convection column development and produces more uniform burning conditions. However, combustion products are held in the lower layers of the atmosphere, especially under temperature inversions, and visibility may be reduced because of smoke accumulation. Do not burn under these conditions. When the atmosphere is unstable, there is a large decrease in temperature with

light. Once air starts to rise, it will continue to rise and strong convection is helpful in venting smoke into the upper atmosphere. In extreme cases, the effect of airmass instability on fire behavior may result in erratic spread rates, spotting, and crowning.

Forecasts of low-level stability, inversion layers, or unstable conditions may be obtained from fire-weather forecasters. Local indicators at the fire site should also be observed. Indicators of stability are steady winds, clouds in layers, and poor visibility due to haze and smoke hanging near the ground. Unstable conditions are indicated by dust devils, gusty winds, clouds with vertical growth, and good visibility. Dust devils usually form when there is very little air movement. These are not desirable conditions for prescribed burns. Burn with steady winds.



The backfire technique consists primarily of starting fire into the wind. Fire is started along a prepared line, such as a road, plowed line, black line, stream, or edge of a forest, and allowed to burn into the wind. Research indicates that variations in wind speed affect the rate at which a fire burning into the wind. For example, with the wind blowing backward at a speed of 1 to 3 miles per hour, the flame is pushed forward at a speed of 1 to 3 miles per hour. This technique is useful for the control and defeat of prescribed fires, provided a steady wind and directional observation. It is usually applied to grass in open fields. The advantages are the time-consuming progress of the fire and the need for interior plowing at frequent intervals, usually every 10 to 20 minutes, to insure burning out of the strips. (Average wind velocities (4 to 10 m.p.h. ground level) are desirable in utilizing this firing technique to that the fire will not extinguish. Burning on slopes or an effort to burn on ridges, or across, down-slope, for example, will give such the same results as backfire in flat country.

Chapter II

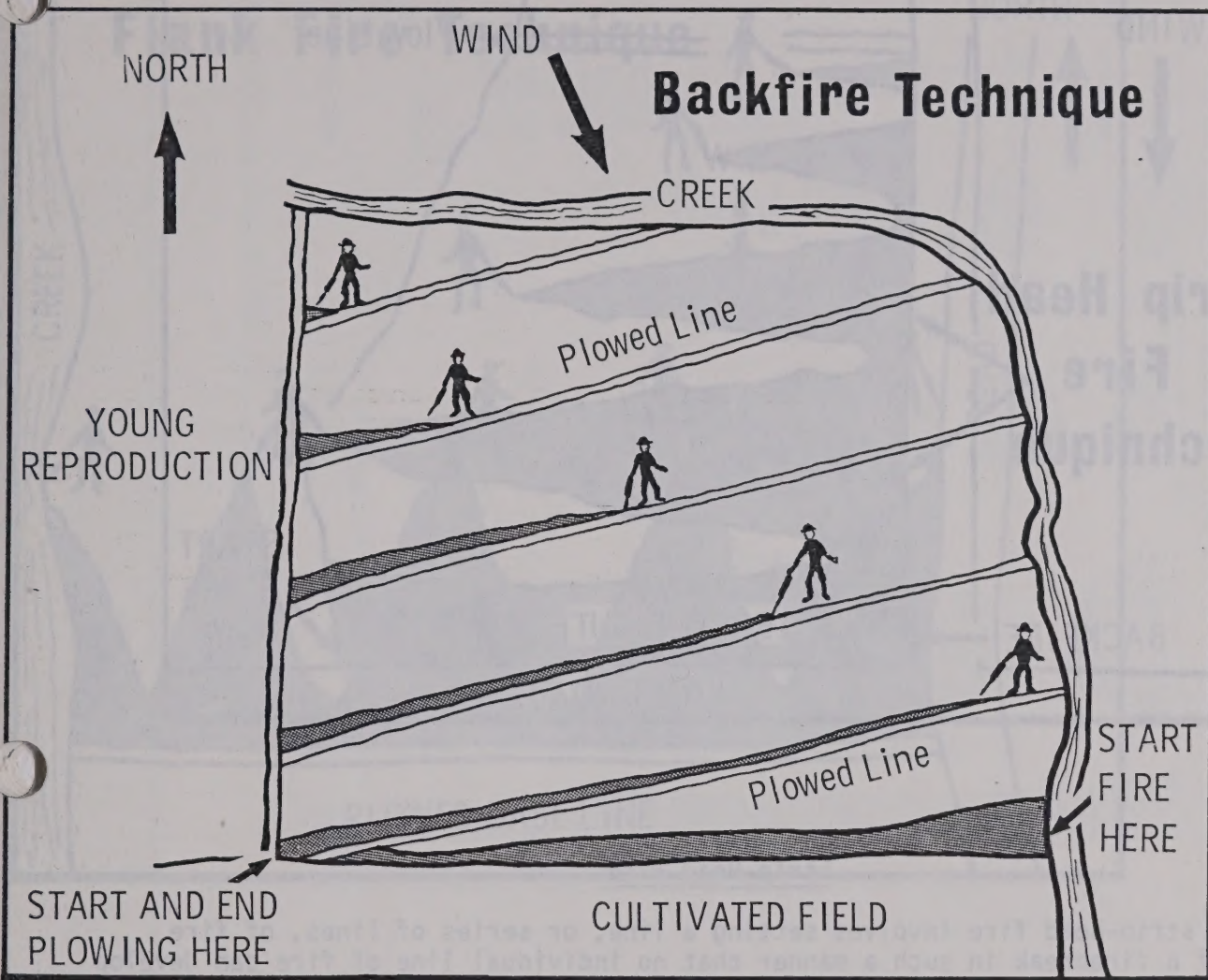
FIRING TECHNIQUES

General

Various firing techniques are available to help accomplish a burn objective under different weather, topography, and fuel conditions. Burning objectives, fuels, and weather factors must be correlated closely with the proper firing technique to prevent harmful effects to the resources.

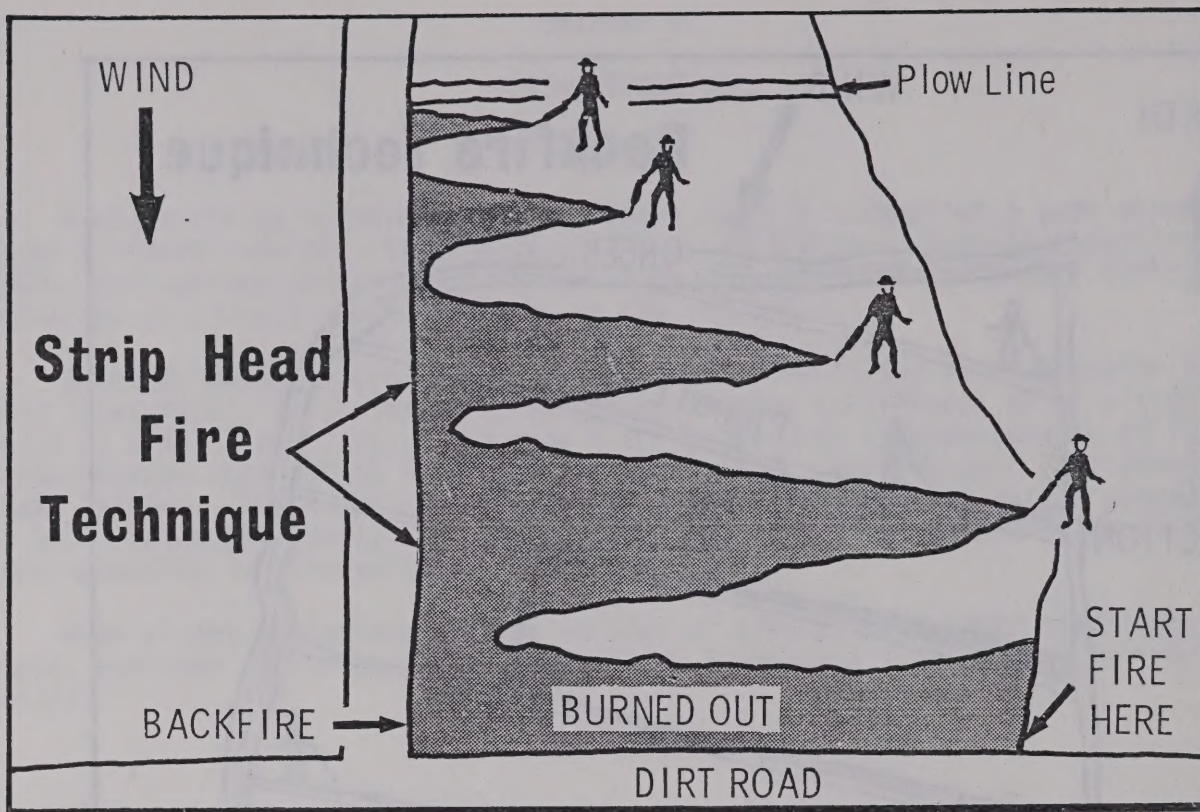
Based on behavior and spread, fires either move in the same direction as wind (head fire), in the opposite direction to wind (backfire), or at a right angle to wind (flank fire). The head fire is the most intense because of its faster spread rate (10 to 20 chains per hour), wider burning zone, and greater flame lengths. The backfire is the least intense--having slow spread rates (1 to 3 chains per hour), a narrow burning zone, and short flames. The flank fire intensity is intermediate.

When slight variations in fuel volumes or prescribed weather conditions occur, consider combining two or more firing techniques to achieve a desired result.



Backfire

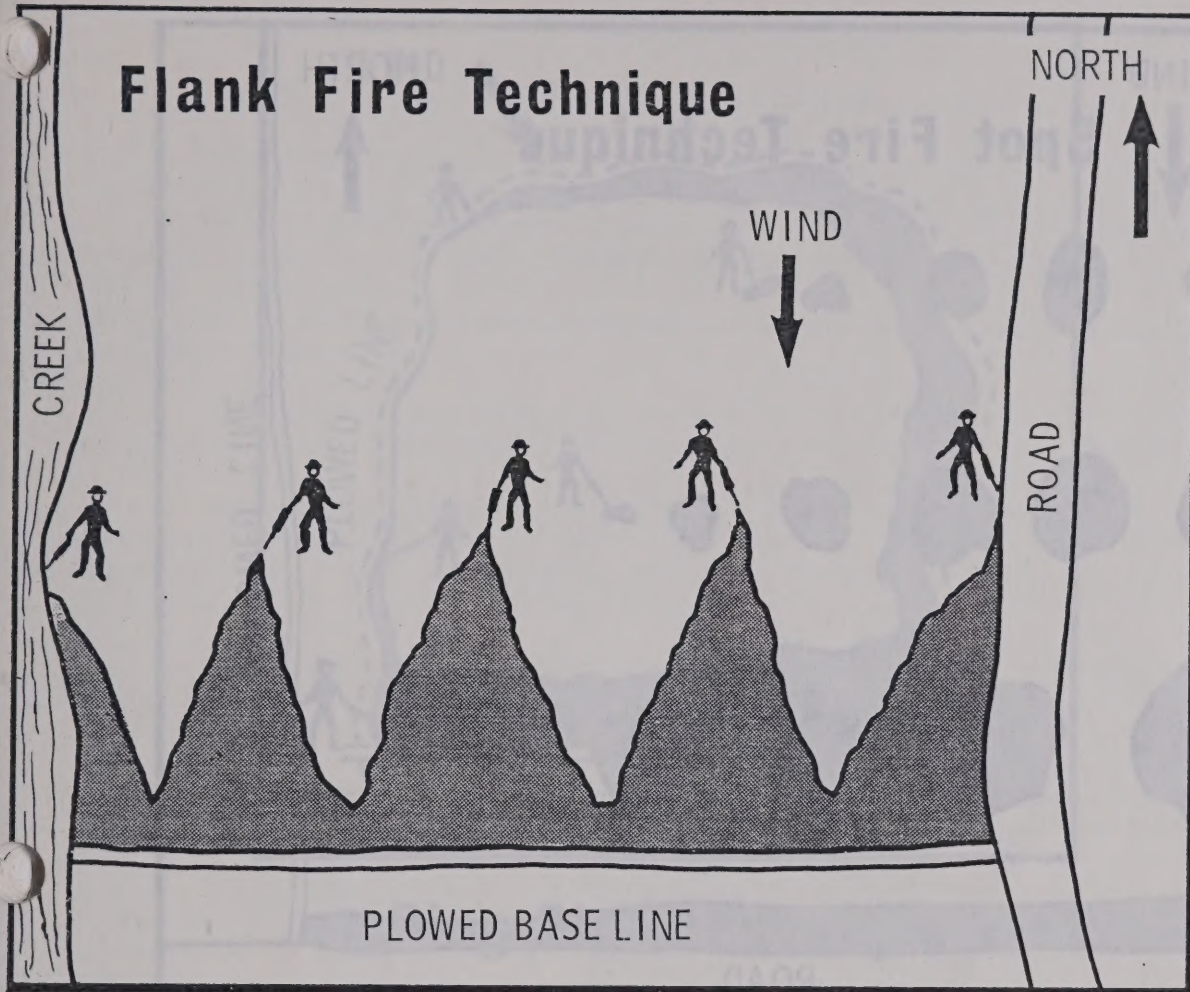
The backfire technique consists primarily of backing fire into the wind. Fire is started along a prepared baseline, such as a road, plowed line, black line, stream, or other form of barrier, and allowed to back into the wind. Research indicates that variations in windspeed have little effect on the rate of spread of fire burning into the wind. Normally, such fire proceeds backward at a speed of from 1 to 3 chains per hour. This technique is perhaps the easiest and safest type of prescribed fire, provided a steady wind (speed and direction) prevails. It lends itself to use in heavy fuels. Some disadvantages are the time-consuming progress of the fire and the need for interior plowing at frequent intervals, usually every 10 to 20 chains, to insure burning out of the strips. Stronger wind velocities (4 to 10 mi/h, ground level) are desirable in utilizing this firing technique so that smoke is well dissipated. Burning on slopes has an effect similar to wind on rate of spread. Downslope fires, for example, would give much the same results as backfires in flat country.



Strip-Head Fire

The strip-head fire involves setting a line, or series of lines, of fire upwind of a firebreak in such a manner that no individual line of fire can develop to a high energy level before it hits either a firebreak or another line of fire. The strips vary in width depending on type, amount, and distribution of fuel and desired results. Usually, strips should be about 1 to 3 chains apart. Frequently, a combination of strip-head fire and backfire is used to treat an area. The base control line would be treated with a backfire, then the remainder of the area treated with strip-head fires. Compensation for minor wind direction changes can be made by altering the angle of strip fire with the baseline. Also, adjustments for fuel density and composition can be made by altering strip widths. This method permits quick firing and smoke dispersal under optimum conditions.

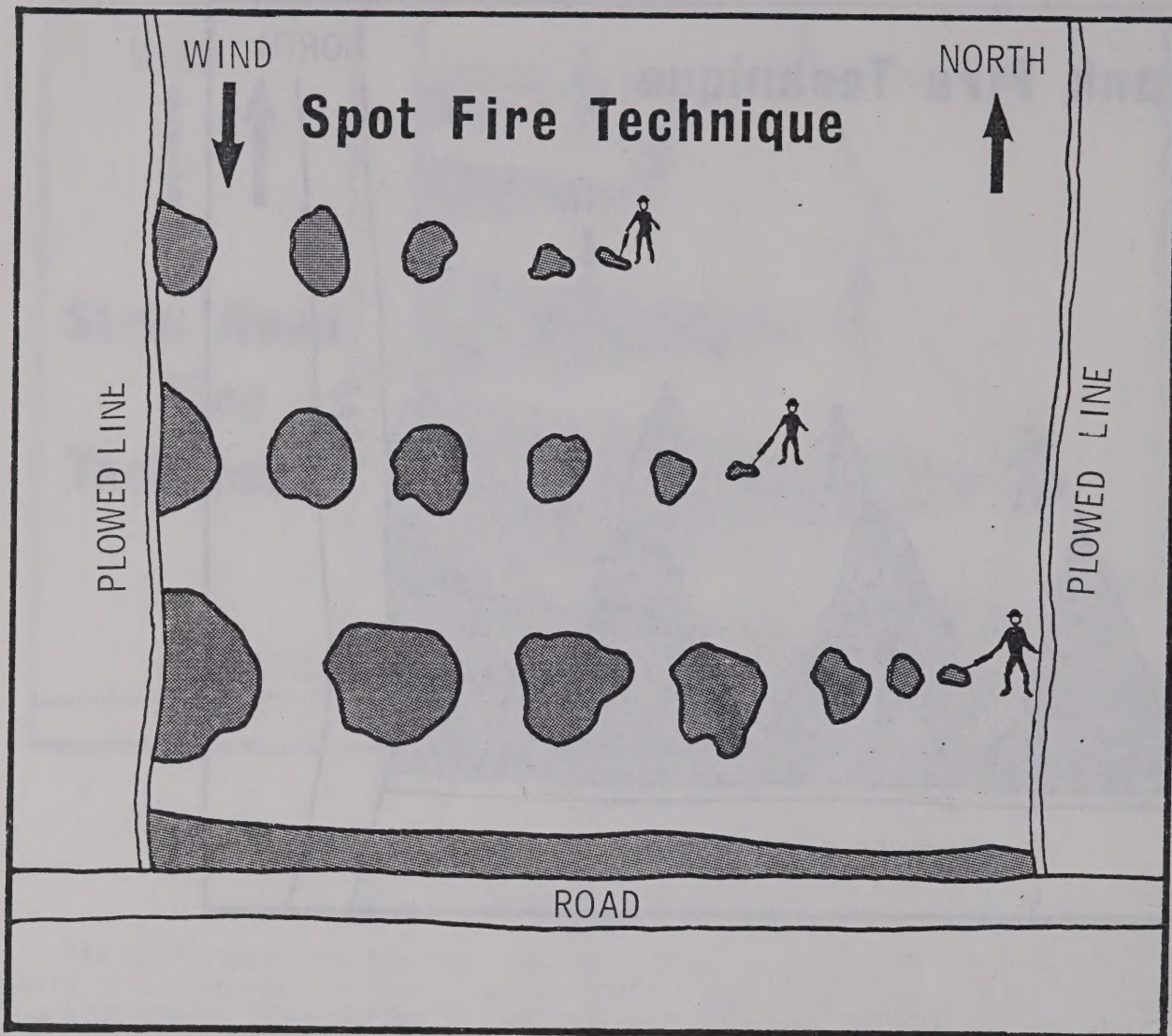
Occasionally, on small areas with light and even fuel distribution a head fire may be allowed to move over the entire area without stripping to better accomplish the objective. Where this method is usable, it would cut down on the areas of increased fire intensity that would occur at junctures of strip fires burning together. CAUTION - Be sure the fire will not escape control. Burn out a strip down-wind with a backfire wide enough to control the head fire.



Flank Fire

The flank fire technique consists of treating an area with lines of fire set into the wind which burn outward at right angles to the wind. This technique also requires considerable knowledge of fire behavior, particularly if used by itself. It is used quite often to secure the flanks of a strip-head fire, backfire, or other methods as they progress. It is sometimes used to supplement a backfire in light fuel areas or under more humid weather conditions.

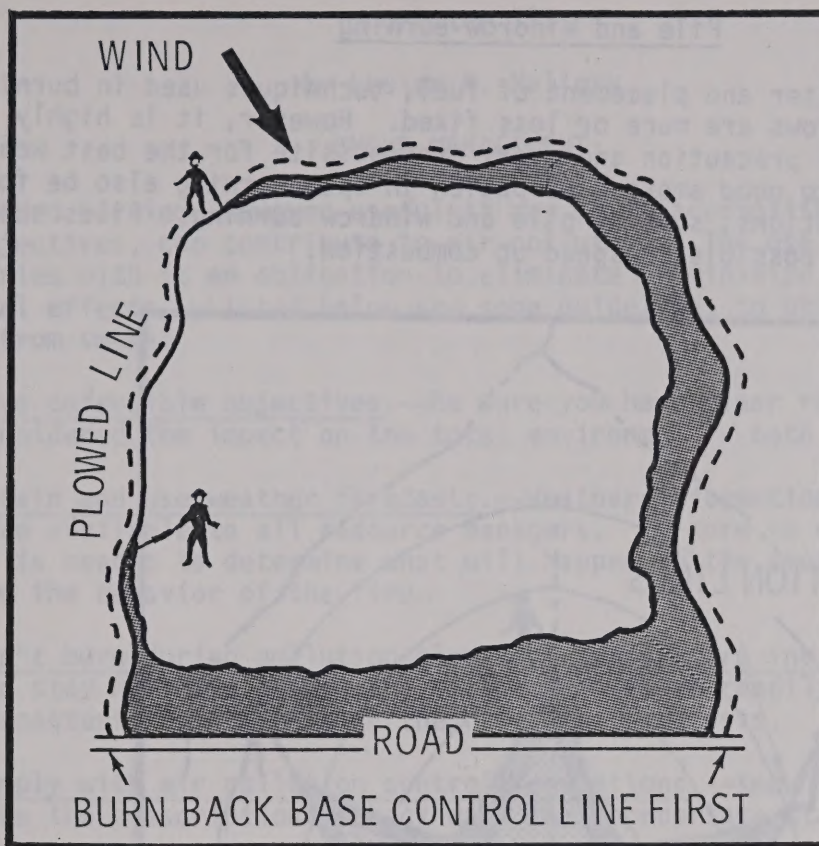
This method of firing can stand little variation in wind direction and needs expert crew coordination and timing. It is useful on a small area or to facilitate burning a large area in a relatively short time.



Spot Fire

The technique of spot firing is an exact procedure which requires considerable experience by the prescribed burner. This method employs a series of small spot fires which burn in all directions as they come together, minimizing the possibility of any one spot gaining sufficient momentum to start a hot run. Timing and spacing of the individual fire spots are the keys to successful application of this method.

Care should be taken not to space spots closer than 2 to 3 chains which would create more junction zones of increased intensity, nor too far apart allowing individual spots to build up hot fire heads. A skilled crew can treat a large area in a short time using this technique. Inexperienced prescribed burners should utilize some other technique until they gain considerable experience in fire behavior. This method can be used with light, variable winds. CAUTION - variable winds may be an indication of instability.



Ring Fire Technique

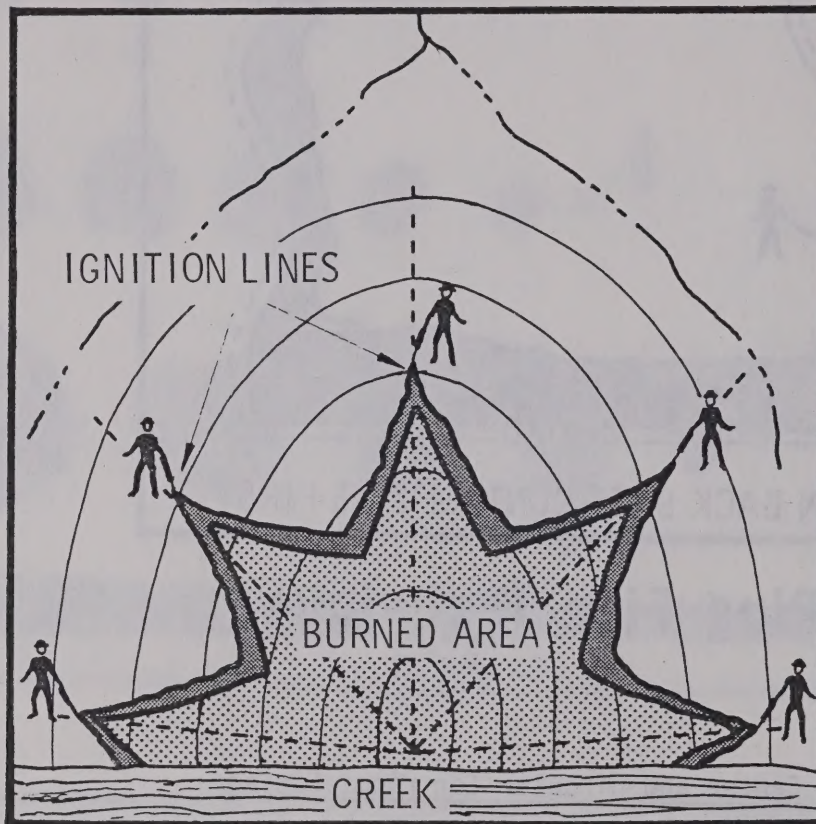
Center and Circular (or ring) Firing

This method of burning is used on areas where a relatively hot fire is needed to reduce or eliminate heavy brush or debris.

As with other burning techniques, a base control line, usually on the downwind side of the burn area, is made secure with back and flank firings. Once the baseline is secured, the entire burn area is circled with fire and allowed to sweep over the area. Often, during periods of light wind, one or more spot fires near the center of the area can assist in pulling the outer circle of fire toward the center. This firing method can generally be used in any season--weather conditions are not as critical. However, caution is in order, particularly when weather conditions border on the unstable. This type of fire is conducive to developing strong and often violent convection columns, spotting possibly up to 1 mile at times.

Pile and Windrow Burning

Due to the character and placement of fuel, techniques used in burning debris piles and windrows are more or less fixed. However, it is highly recommended that every precaution and every prerequisite for the best weather conditions conducive to good smoke dissipation in open burning also be followed in fixed burning situations, such as pile and windrow burning. Piles should be as free of soil as possible to speed up combustion.



Chevron Ring Technique

Chevron Burn

This technique of prescribed firing is designed for use in hilly areas to fire ridge points or ridge ends. Lines of fire should be started simultaneously from the apex of a ridge point, and progress downhill. Basically, it involves a flank fire concept except that the lines of fire are not parallel. Any two lines of fire converge at a point rather than along a line, resulting in the junction zones or areas of increased intensity remaining small. The chevron technique alone is not suited to most topography and should be used only in combination with other techniques.

Chapter III

by Lester P. Mallory

SMOKE MANAGEMENT

Prescribed burning, however useful it may be in accomplishing certain resource objectives, can contribute to air pollution. The use of prescribed burning carries with it an obligation to eliminate or minimize any adverse environmental effects. Listed below are some guidelines to observe in reducing the impact from smoke:

1. Have defensible objectives.--Be sure you have clear resource objectives and have considered the impact on the total environment - both onsite and offsite.

2. Obtain and use weather forecasts.--Weather information and fire-weather forecasts are available to all resource managers. Be sure to use them. Such information is needed to determine what will happen to the smoke, as well as to determine the behavior of the fire.

3. Don't burn during pollution alerts or temperature inversions.--Smoke will tend to stay near the ground and will not disperse readily. Many fire-weather forecasters include this in their regular forecasts.

4. Comply with air pollution control regulations.--Know the regulations when you make the prescription. Check with the appropriate State agency.

5. Burn when conditions are good for rapid dispersion.--The atmosphere should be slightly unstable so smoke will rise and dissipate - but not so unstable as to cause a control problem. Again, your fire-weather forecaster can help.

6. Determine the direction and volume of smoke.--This is especially important near highways and populated areas. Smoke management guidelines will help in making these determinations.

7. Use caution when near or upwind of smoke-sensitive areas.--Burning should be done when wind will carry smoke away from heavily traveled roads, airports, and populated areas.

8. Notify the local fire control office, nearby residents, and adjacent landowners.--This is not only common courtesy, but a requirement in many areas. Keep the public informed. They should know whether smoke is from a wildfire or a prescribed burn. Prior notification will give you advance notice of any adverse public reaction--such as people with respiratory ailments, washday, etc.

9. Use test fires to confirm smoke behavior.--Set these in the area proposed for burning, away from road or other "edge" effects.

10. Use backfires when possible.--Backfires result in more complete consumption of fuel and produce less smoke. Even though slower and more expensive, fewer pollutants are put into the air and visibility is less restricted.

11. Burn in small blocks.--The larger the area being burned, the more visibility is reduced downwind and the higher the concentration of particulates put into the air. However, it may be better to burn all the area needed when weather conditions are ideal for rapid dispersion of smoke.

12. Mopup along roads.--Burn out and start mopup along roads as soon as possible to reduce impact on visibility.

13. Be cautious of nighttime burning.--Predicting smoke drift and visibility is more difficult at night. The wind may lessen or die out completely and smoke will tend to stay near the ground. Burn at night only when you have a definite forecast of optimum conditions.

14. Have an emergency plan.--Be prepared to control traffic on nearby roads if wind changes direction. Be prepared to stop a prescribed burn if it is not burning according to plan or if weather conditions change.

Chapter IV

INCORPORATING FIRE MANAGEMENT IN ACTIVITY PLANS

In reviewing the BLM Manual instructions for the preparation of activity plans for Range, Wildlife, and Watershed, an underlying theme comes through loud and clear. After the objectives of the plan are established, the vegetation is to be managed and/or manipulated to achieve those objectives. This means management in favor of some species of vegetation and against others. Or, it may mean maintaining the vegetative composition in adjacent areas in a variety of seral stages. Once the objectives are set and the manager decides on which species he wants to encourage and which he wants to discourage, he can use these guidelines and decide whether and how he wants to use fire as one of the many land treatment tools available to him in achieving those objectives.

Two principal factors must concern him in this process--fire effects and fire behavior.

Fire Effects

Fire may have a beneficial or detrimental effect on vegetation, depending upon the management objectives. The effect varies by species and by season of the year. Fire may enhance a desirable species while damaging an undesirable. In other cases, the reverse may be true. For instance, under certain conditions, bluebunch wheatgrass can increase in abundance after a fire while big sagebrush will decrease dramatically. On the other hand, antelope bitterbrush may be severely damaged while rabbitbrush increases. See Chapter V for an in-depth discussion of fire effects in your area.

Fire Behavior

If the manager is to attain the desired fire effects, he must have an appreciation of fire behavior and the various factors that govern how a fire burns. He will want the right fire at the right time to accomplish the stated objectives. He will also want to guard against escapes and disaster fires. Consultation with the District Fire Management Officer will help on this subject.

Procedures

Chapter V contains writeups on several plant species found in your area. The information is not all inclusive, but should cover most situations. As experience adds to his knowledge, the manager is encouraged to produce additional writeups for his area.

In order to determine whether fire can be used on an area and if so, what kind of a fire it should be, the manager should do the following:

1. Examine the fire effects writeups for the plants pertinent to the area.
2. Summarize key words on a table or matrix if necessary.
3. From this array, the manager should be able to make an informed judgment concerning the use of fire. If his decision is strict fire control, that should be so stated in his activity plan and in the Fire Management Activity Plan.

If fire use is the decision, he should spell out in the activity plan the conditions under which it is to be done:

1. Schedule (i.e., every 15 years after initial burn).
2. Season (spring, summer, fall, winter, or a particular month).
3. Intensity desired (i.e., clean burn--prefer islands left, etc.).
4. Restrictions for favoring certain plants (i.e., burn only under certain soil moisture conditions to favor sprouting of bitterbrush).

Also, if fire use is contemplated, it must be discussed in any EAR/ES which is written on the activity plan. The environmental effects can be:

1. Short range -

Discuss such things as smoke, temporary denuding of the landscape (esthetics), temporarily exposed bare soil, etc.

2. Long range -

Discuss such things as possible diminution or eradication of some species, dangers in slow recovery of vegetation and erosion potential, possible permanent change in esthetics (mosaic appearance instead of uniform vegetation), etc.

The environmental effects may be good, bad, or neutral, depending upon the plan objectives, but there will be effects.

The pertinent portions of the activity plans (AMP, HMP, etc.) should be used in the District Fire Management Activity Plan.

CHAPTER V
FIRE EFFECTS
by Henry A. Wright and Rita Thompson
SOUTHERN GREAT PLAINS

1

Shortgrass Prairie

<u>Growth Form</u>	<u>Species</u>	<u>Fire Effects</u>	<u>Remarks</u>	
<u>Grasses</u>	Buffalograss	) Decreased for 2 to 3 years after burning during drouth years; Buffalo-grass and blue grama not harmed when winter and spring precipitation are above normal.	But tolerant when winter and spring precipitation were 40% above normal. Based on data from wildfire during a below average precipitation year. Based on data from sand shinnery oak areas in Oklahoma. Based on data from sand shinnery oak areas in Oklahoma.	
	Blue grama			
	Red threeawn	) Generally decreased by fire		
	Sand dropseed			
	Galleta	) Generally decreased by fire		
	Ring muhly			
	Slim-Stemmed muhly			
	Wolf-tail			
	Little bluestem	Production decreased after burn		
	Tumble windmill grass	Not harmed by fire		
Sand bluestem	) Production increased after burn	Based on data from sand shinnery oak areas in Oklahoma.		
Switchgrass				
Weeping lovegrass			) Not harmed by fire	
<u>Forbs</u>	Annual broomweed	) Harmed by spring burning	Generally, forbs are harmed more by spring burns than fall burns.	
	Horsetail			
	Silverleaf nightshade			
	Western ragweed			
	Rabbit's tobacco	) Not affected by spring burning		
	Warty euphorbia			
	Woolly plantago			
False mesquite	Favored by spring burning			

SOUTHERN GREAT PLAINS

2

Shortgrass Prairie

<u>Growth Form</u>	<u>Species</u>	<u>Fire Effects</u>	<u>Remarks</u>
V-2 Shrubs	Mesquite	Fire tolerant	Exceptional sprouters, especially on the High Plains. Seedlings reasonably tolerant of fire when they are over one year old. A February burn reportedly killed 31% of seedlings less than one year old.
			Repeated burns will keep mesquite in check.
	Shinnery oak	Fire tolerant	Increased 15% following fire, but produced no acorns during year of burn.
	Algerita	Fire tolerant sprouters	Fourwing saltbush is palatable and is fully recovered 3 years after being burned.
	Aromatic sumac		
	Chickasaw plum		
	Fourwing saltbush		
	Skunkbush sumac		
	Winterfat		
	Sand sage	Fire intolerant	Is killed by fire, but produces abundant seedlings after burning.
	Cacti (Opuntia)	Fire intolerant	50 to 80% of most species are killed, especially if they are less than 2 ft tall. Large clumps of pricklypear or tall cholla usually survive fires.

Mixed Prairie

<u>Grasses</u>	Sideoats grama (rhizomatous form)	Intolerant	More tolerant in wet years - yield decreased 51% in dry years vs. 12% in wet years. Takes at least 3 years to recover after being burned during dry years.
	Little bluestem	Tolerance is moisture dependent	Decrease about 50% dry years, but will increase as much as 81% during wet years after a spring burn.
	Tobosagrass	Very tolerant	Burning increases production 2 to 3-fold and palatability 10-fold when precipitation is average or higher. When precipitation is below average, yields may be reduced 20 to 50%. Never burn more than 1/5 to 1/8 of a pasture each year.

SOUTHERN GREAT PLAINS

5

Mixed Tallgrass-Forest

<u>Growth Form</u>	<u>Species</u>	<u>Fire Effects</u>	<u>Remarks</u>
<u>Grass</u>	Little bluestem	Tolerant	No fire research has been done. Interest current in using fire on 4 yr. rotation to keep oak sprouts suppressed in bluestem pastures. Based on this precipitation zone and fire effects data from other areas, little bluestem should be very tolerant to fire.
<u>Trees</u>	Blackjack oak Post Oak	} Easily top-killed but resprout } vigorously	

V-5

CENTRAL GREAT PLAINS

1

Tallgrass Prairie

9-A

<u>Growth Form</u>	<u>Species</u>	<u>Fire Effects</u>	<u>Remarks</u>	
<u>Grasses</u>	Canada bluegrass	} Severely harmed	Generally an 80% reduction. Cool season species.	
	Kentucky bluegrass			
	Canada wildrye	} Harmed		Smooth brome is more tolerant to early spring burns than other cool season species because it does not germinate until mid-May.
	Japanese brome			
	Smooth brome			
Virginia wildrye				
	Fall witchgrass	) Favored		
<u>Forbs</u>	Dotted gayfeather	} Tolerant	Most species favored by fire, but some people have reported decline for prairie clover and goldenrod.	
	False boneset			
	Missouri goldenrod			
	Plains wild indigo			
	Prairie sunflower			
	Silky prairie clover			
	Goosefoot	} Harmed		
	Gromwell			
	Heath aster			
	Pepperweed			
	Pigweed			
	Prairie coneflower			
	Virginia day flower			
	Woolly plantain			
	<u>Shrubs</u>	Missouri spurge		} Unchanged
Western ragweed				

CENTRAL GREAT PLAINS

2

Short Grass and Mixed Prairie

<u>Growth Form</u>	<u>Species</u>	<u>Fire Effects</u>	<u>Remarks</u>
<u>Grasses</u>	Buffalograss	) Allow 2 to 3 yrs. for recovery during dry years; not harmed when precipitation is above normal	Buffalograss-blue grama mixture recovered 35, 62, and 97% following the first, second, and third growing seasons after being burned in the spring during a dry year.
	Blue grama		
	Western wheatgrass		Western wheatgrass recovered 18, 27, and 77% respectively during the same growing seasons.
	Big bluestem	) Harmed by fire during dry years	No data for wet years, but would probably tolerate fire.
	Hairy grama		
	Hairy sporobolus		
	Little bluestem		
	Sideoats grama		

Forbs See data for Southern Great Plains

Tallgrass Prairie

<u>Grasses</u>	Big bluestem	) Very tolerant	Production often doubles after burning, unless burned annually. If burned annually, burns should be conducted about May 1. Drouth is rarely a problem in this rainfall belt.
	Indiangrass		
	Little bluestem		
	Switchgrass		
	Blue grama	) Generally no change to a slight increase	
	Buffalograss		
	Hairy grama		
	Prairie junegrass		
	Prairie sand dropseed		
	Sideoats grama	)	

NORTHERN GREAT PLAINS

1

Mixed Grass Prairie

<u>Growth Form</u>	<u>Species</u>	<u>Fire Effects</u>	<u>Remarks</u>
8-A <			

NORTHERN GREAT PLAINS

2

Mixed Grass Prairie

<u>Growth Form</u>	<u>Species</u>	<u>Fire Effects</u>	<u>Remarks</u>
<u>Shrubs</u>	Arkansas rose	) Reduced by spring burning	
	Fringed sagebrush		
	Silver sagebrush		
	Herbaceous sage	) Increased after spring burning	

Tallgrass Prairie (True Prairie)

<u>Grasses</u>		
	Big bluestem	)
	Blue grama	)
	Indiangrass	)
	Leiberg panicum	)
	Little bluestem	) Increase after spring burning
	Prairie cordgrass	)
	Prairie dropseed	)
	Prairie sandreed	)
	Saltgrass	)
	Wheatgrasses	Increased on upland sites, but declined on lowland sites.
	Bearded wheatgrass	)
	Canada bluegrass	)
	Foxtail barley	)
	Junegrass	)
	Kentucky bluegrass	) Usually harmed by fire, but some data
	Muhlenbergia sp.	) shows no change and some shows an
	Quackgrass	) increase
	Rushes	)
	Slender wheatgrass	)
	Smooth brome	)

Some of this information is based on frequency data and may or may not reflect yields.

Eastern North Dakota study.

Increased on upland sites, but declined on lowland sites.

Usually harmed by fire, but some data shows no change and some shows an increase

Usually harmed by fire, but some data shows no change and some shows an increase

NORTHERN GREAT PLAINS

3

Tallgrass Prairie (True Prairie)

<u>Growth Form</u>	<u>Species</u>	<u>Fire Effects</u>	<u>Remarks</u>
V-10	<u>Forbs</u>		
	Erigeron	)	
	Goldenrod	)	
	Ragweed	)	
	Rattlesnake master	)	
	Tall gayfeather	)	
		Increase after spring burning	See Table 3 of Chapter VIII for other forbs that increase after burning.
	Atlantic wild indigo	)	No change
	Heath aster	)	Variable responses
			Declined in eastern North Dakota, but increased with spring burning in Wisconsin.
	Canada thistle	)	
	<u>Oxalis stricta</u>	)	
	<u>Prairie clover</u>	)	
	Purple coneflower	)	
	<u>Trifolium repens</u>	)	
	Wild parsnip	)	
		Declined after spring burning	
	<u>Shrubs & Trees</u>		
	Arkansas rose	)	
	Western snowberry	)	
		Increase after spring burning	
	Scrub oak	)	
		Increases with fire exclusion	

Growth Form	Species	Fire Effects	Remarks
Grasses	Agropyron-type communities	Reduced yields up to 50% following spring burning during a dry year. Effects of fall burning less pronounced - production decreased by 30% first year with recovery second year.	Agropyron-type communities more sensitive to spring burning than Blue grama and needle-and-thread.
	Blue grama - Needle-and-thread communities		
	Bearded wheatgrass		
	Slender wheatgrass		
	Western porcupine grass	No change in cover after spring burn with good moisture; fall burns harmful	Fall burning severely harmed the wheatgrasses.
	Prairie sandreed	Increased with annual spring burns	Western porcupine grass was reduced 25 to 30% by fall burns.
	Sedge		
	Hooker's oatgrass		
	Parry oatgrass		
	Rough fescue	Harmed by spring burning.	Rough fescue required 3 years for full recovery. It tolerates fall burns better than spring burns.
Sedge			
Timothy			
Forbs	Bedstraw	Increased after spring and/or fall burning	
	Bushpea		
	Milk vetch		
	Missouri goldenrod		
	Stickseed		
	Three-flowered avens		
	Western yarrow		
	Woundwort		
Little club moss	Seriously harmed by spring and fall burns		
Shrubs	Fringed sage	Seriously harmed by spring and fall burns	
	Silverberry		
	Silver sagebrush		

CANADIAN GREAT PLAINS

2

<u>Growth Form</u>	<u>Species</u>	<u>Fire Effects</u>	<u>Remarks</u>
<u>Shrubs</u>	Arkansas rose	) Moderately harmed	Desired frequency for shrub control is probably 5 to 10 years. Forage losses can be minimized by using fire only during those springs preceded by normal to above normal precipitation.
	Rosa acicularis		
	Western snowberry		
	Herbaceous sage	) Increased dramatically	
	Raspberry		

V-12

Chapter VI

FIRE USE PLAN

by William C. Fischer

Introduction

The purpose of this chapter is to suggest a fire use plan and report format that is consistent with both the philosophical and the activity related concepts of fire management. Acceptance of the proposed format would also serve the purpose of providing a standard terminology. For example, the terms fire prescription and burning plan are often used as synonyms. In the suggested format these terms have very specific and different meanings. This chapter lists the elements that should be considered when planning fire use. It does not tell how detailed the information relating to these elements needs to be. The required resolution and precision of needed information should be specified in prescribed fire guidelines. These guidelines can be written for local or regional areas or for individual vegetative types. The fire use planning format suggested here can be used as an outline for the organization and content of such prescribed fire guides.

Fire Use Planning--

From a fire management perspective, a successful prescribed fire is one that is executed safely, burns under control, accomplishes the prescribed treatment, and attains the land and resource management objectives for the area involved. Successful prescribed burning requires planning. Such planning should be based on the following factors:

1. Physical and biological characteristics of the site to be treated.
2. Land and resource management objectives for the site to be treated.
3. Known relationships between pre-burn environmental factors, expected fire behavior, and probable fire effects.
4. The existing art and science of applying fire to a site.
5. Previous experience from similar treatments on similar sites.

The proposed fire use plan is designed to direct the prescribed fire planner through the above factors in a logical sequence. The proposed report is designed to provide written record of actual prescribed burning experience that the planner can use when writing subsequent plans. The actual form of the resultant plan is left to the judgment of the planner or to the needs of his employer. Some prefer fill-in-the-blank type plans while others favor narrative type plans that vary in composition according to the complexity of the planned fire. The primary concerns here are the thought process involved in planning fire use and the technical validity of the plan produced. One final point before considering the proposed format: It is assumed the decision to use fire has already been made. It is further assumed the decision to burn is compatible with land and resource management objectives for the area and these objectives are defensible from an ecological standpoint.

The Fire Use Plan and Report--

The fire use plan and report format is in four parts. The first part deals with the planned fire treatment and the site to be treated. The prescribed fire planner is asked to describe the biological and physical characteristics of the site and to define the treatment objectives in terms of land and resource management objectives. The planner is also asked to identify all constraints that bear upon how prescribed fire can be applied to the area.

The information assembled in Part 1 is used to write the fire prescription, which is Part 2 of the proposed format. The first step in writing a fire prescription is to further define the treatment objectives in terms of the type and amount of work the fire must do. This is a critical task in the planning process. How well the fire accomplishes the desired work becomes the measure by which success or failure of the prescribed fire will be judged. Once the fire's work has been specified, the planner must draw upon existing knowledge of fire behavior and fire effects to determine (1) the type of fire behavior desired, (2) the environmental conditions under which the fire is likely to behave as desired, and (3) the burning techniques that must be used to get the fire to behave as desired under these environmental conditions.

The burning plan, Part 3 of the proposed format, is based upon the fire prescription. The burning plan is the action plan, or project work plan, for a prescribed fire. It translates the fire prescription into on-the-ground tasks that must be performed before, during, and after the actual fire. For each identified task, the plan should tell when and how it will be done and who will do it. The needed equipment and supplies are listed and the cost of the project is determined. A properly prepared burning plan becomes the only document needed by the people responsible for conducting the planned prescribed fire.

A standard EAR must be written for each burning plan under procedures set out in the BLM manual.

Part 4 of the report is designed to evaluate the plan in terms of the fire and its effects. The purpose of this evaluation is to provide valuable information for future fire use planning efforts. Too often such information is lost or only partially used by prescribed fire planners. Prescribed fire planners should keep a file of those reports, indexed appropriately for fast retrieval, and use them as a tool for fine-tuning subsequent fire prescriptions and burning plans. Fire information systems such as FIREBASE (Taylor and Eckels, 1977) might be used to store and retrieve such information.

An expanded outline of the proposed fire use plan and report format follows:

Part 1 - Treatment Area And Objectives

Purpose of Plan - State briefly and in general terms the type of treatment planned and its purpose.

For example:

--prescribed broadcast fire for hazard reduction and site preparation on a 35-acre clearcut unit containing larch/fir logging slash.

--prescribed broadcast fire for elk winter range improvement on a 500-acre low elevation mountain shrubland.

--prescribed broadcast fire for rejuvenation of 350 acres of little bluestem grassland.

The only purpose of this statement is to identify the type of activity being planned. Such a statement would logically follow the decision to use fire, which has already been made.

Treatment Area - Identify and describe the physical and biological characteristics of the area to be treated. Use maps, graphs, tables, etc., to show:

--size of area

--location

--elevation

--landforms (slope and aspect)

--soil types (erodibility, susceptibility to damage)

--vegetation (species, cover types, habitat types)

--down and dead fuels (amount, size class distribution, depth, continuity, etc.)

--climate and weather patterns (seasonal averages, probability of occurrence of different weather patterns, etc.)

--wildlife and wildlife habitats

Information on the above items often exists in ready to use form in land management plans, environmental statements and reports, resource management plans, and summaries of land and resource inventories.

Land Management Objectives - Summarize, very briefly, the land and resource management objectives and management guidance for the area to be treated. Refer to appropriate land management plans, resource management plans, silvicultural prescriptions, fire management plans, and other sources. For example:

Management Objectives--The management objectives for the lands within this management unit are to (1) protect the aquatic environment by maintaining

water quality for on and offsite use, (2) maintain the visual quality of the unit as reviewed from the major travel routes, and (3) manage the timber resource to maintain a healthy, productive forest within constraints imposed by watershed and visual concerns.

Management Guidance--Slash disposal will be complete enough to provide for free movement of wildlife through the management unit. Generally this means that slash concentrations more than 1-1/2 feet deep must be eliminated.

Treatment Constraints - Identify and define all constraints that bear upon how treatment can be applied. Consider:

- environmental constraints (air quality, water quality, accelerated erosion)
- multiple use constraints (protection of other uses, resource management trade-offs)
- economic constraints (maximum cost/acre)
- operational constraints (access, terrain, manpower, etc.)
- administrative constraints (agency policy, rules, etc.)
- legal constraints (State fire laws, forest practice acts, etc.)

Constraints are usually identified in the land management plan for the area to be treated. Other sources are agency rules, regulations, and policy; State and Federal laws; production rates and operational capabilities of men and machines; and project budgets.

Treatment Objectives - State in terms of land or resource management objectives referred to above and any constraints listed in the previous section. For example:

- reduce potential rate-of-spread to "low," provide for free movement by wildlife, regenerate area naturally with 1,000 western larch seedlings per acre.
- increase the amount of redstem ceonothus on the area, rejuvenate decadent shrubs to make them more available and palatable for elk and set back conifer encroachment.

Treatment Alternatives - Identify acceptable alternatives to the use of fire, if this was not done preceding the decision to use fire. State why they were not chosen.

This information can be important under certain circumstances whereby the manager must set priorities for burning because of time or manpower constraints. For example, if a shorter than expected prescribed burning season develops due to persistence of adverse summer burning conditions into the fall. In such a situation, efforts can be concentrated on burning those areas for which no acceptable non-fire alternative exists.

Part 2 - Fire Prescription

Treatment Specifications -

Desired Accomplishment--State, in precise terms, the work the fire needs to do, i.e.:

- inches or percent of duff to be removed
- amount or percent of fuels to be reduced by size class
- amount or percent of mineral soils to be exposed
- vegetation to be killed or otherwise treated by species

Desired Fire Behavior--Define the kind of fire needed to accomplish desired work while complying with any treatment constraints listed.

- rate-of-spread (fast or slow--specify acceptable range)
- fire intensity (hot or cool--specify acceptable range)
- flame height (especially if burning under a timber stand)
- flame length

To obtain this information, use prescribed fire guidelines, fire models, fire effects literature, consultation with experts, etc.

Required Environmental Conditions--Define the conditions, or range of conditions, necessary to obtain the desired fire behavior and effects. Use prescribed fire guidelines, fire models, consultation with experts, etc., consider:

- fuel moistures
- duff moisture
- windspeed and direction
- soil moisture
- temperature
- relative humidity
- physiological condition of vegetation (cured, dormant, etc.)

Treatment Strategy - Describe the sequence of events needed to achieve the treatment objectives and identify the tasks necessary for success.

- preburn tasks (slashing, snag felling, fireline construction, etc.)
- ignition technique (strip headfire, center fire, etc.)

--ignition methods (remote, drip torch, grenades, etc.)

--firing pattern or sequence

Pre-Burn Monitoring - Briefly describe how the area will be monitored to decide when conditions, specified above, are correct for burning. Indicate the measurements to be taken, where they will be taken, and the precision needed. Consider the need for fuels inventory, fuel and duff moisture measurements, weather measurements, etc.

Evaluation - Briefly describe how the treatment area will be evaluated to determine if treatment objectives, specified above, were met. Specify measurements to be taken during the fire to evaluate fire behavior and measurements to be taken after the fire to evaluate fire effects.

Part 3 - Burning Plan

Preparation for Burning - For each preburn task identified in the prescription, specify:

- what will be done
- when it will be done
- how it will be done
- who will do it
- equipment and supplies needed
- cost

Pre-Burn Monitoring - For each monitoring task identified in the prescription, specify:

- what will be done
- when it will be done
- how it will be done
- who will do it
- equipment and supplies needed
- cost

Ignition - On a map of the area to be burned, indicate ignition plan. Show sequence of ignition, placement of ignition crew, kind and location of ignition devices, etc., specify:

- what will be done
- when it will be done
- how it will be done
- who will do it
- equipment and supplies needed
- cost

Holding - Indicate on a map of the burn area placement of men and equipment for holding fire in planned area. Indicate how escapes will be dealt with, specify:

- what will be done
- when it will be done

- how it will be done
- who will do it
- equipment and supplies needed
- cost

Mop-up - Describe plans for mop-up and/or patrol after the fire has been conducted. Specify:

- what will be done
- when it will be done
- how it will be done
- who will do it
- equipment and supplies needed
- cost

Evaluation - For each evaluation task listed in the prescription, specify:

- what will be done
- when it will be done
- how it will be done
- who will do it
- equipment and supplies needed
- cost

Cost Summary - Summarize planned costs for manpower, equipment, and supplies.

Part 4 - Report

Accomplishment - State in precise terms the actual accomplishment of the fire. For example, 3 inches of duff removed; 20% of area bare to mineral soil. Relate this to the desired accomplishment listed in the fire prescription.

Timing of fire effects evaluation is important. Some effects are apparent immediately after the fire and should be evaluated within a week. Other effects might not be apparent until the start of the subsequent growing season. In such situations, the report should be revised to include the longer-term effects after they have been evaluated.

Fire Behavior - State the actual fire behavior that occurred. Relate this to desired fire behavior described in the fire prescription. Quantify, if possible.

Environmental Conditions - State the actual fuel moisture, weather conditions, and other designated environmental factors that preceded the fire and that occurred during the fire. Relate to those specified in the fire prescription.

Cost - State actual costs incurred. Explain any differences from estimated costs.

Observations and Recommendations - Summarize significant aspects of the fire in relation to expectations. Relate what actually happened to what was expected to happen. Indicate knowledge gained that should be considered when planning subsequent prescribed fires. For example (Norum, 1975):

Experience gained during this fire indicates a need to modify the ignition procedure for future hazard reduction burns in this fuel type. Because of the concentrated and discontinuous nature of the fuels, fires ignited across the lower edge of a plot often burned vigorously until a fuel discontinuity was reached, whereupon the fire went out. The result was a very ragged burn with hazardous fuel left in the center of the unit. Control and containment difficulties were experienced when ground fuels were sufficiently dry to carry fire between concentrations. Crown fires began to increase in frequency, and spotting outside of the prescribed area required alert patrol and vigorous suppression. Based on the results of this experience, I suggest ignition of strips of fuel across the slope, beginning at the upslope perimeter and progressing to the bottom of the plot. Permit each strip of ignited fuel to burn until the level of maximum intensity passes, then ignite the next downslope and adjacent strip. This procedure should assure ignition of all fuels and minimize control problems.

Chapter VII
PRESCRIPTION GUIDES
by Henry A. Wright

Following a list of printed instructions will not teach you how to ride a bicycle. You must get on the bicycle and practice to learn to ride it. However, having learned something of the feel of riding a bike, the novice rider can read or listen to more experienced riders on ways to improve his riding, increase efficiency of effort, speed, ease, comfort, safety, or satisfaction. The same is true for learning how to conduct prescribed burns.

There is a lot of "art," and there are a lot of unforeseen circumstances that are peculiar to each burn. Nevertheless, experience is the best teacher. We learn by doing. And by doing we learn rapidly. An experience with a wildfire can be frightening, but prescribed burning is not as dangerous as wildfires. It is just dangerous to be inexperienced! And it is very dangerous to be half-experienced, for in this situation the person who becomes overconfident will have fires get away from him.

Models for prescriptions can be helpful in the planning phases of a burn, but they don't protect you against the intangibles--a hill on the side of a pasture that might cause unusual winds, a canyon on the lee side that may aid the formation of an intense firewhirl that will throw firebrands at greater distances than normal, unusual fuel densities that can create intense firewhirls, possibility of a night-time low-level jet of wind at 3,000 ft elevation, volatile fuel material, etc. Generally, most people who conduct fires consider most fire danger index models, etc., to be too complicated and too time consuming to be useful. They usually use two to four variables in the decisionmaking process as to whether or not to burn.

The secret to all prescribed burning is to let the weather do the work for you. When all environmental factors are right, the job is easy. However, if the relative humidity is below 20% if you are depending on a low pressure trough in late afternoon for your wind direction, if air temperature is above 80°F, or if average wind speeds are above 15 mph, prescribed burning can be a miserable job. On the other hand, don't be too cautious. Set a fire that will accomplish your objectives. The prescription that we like for most headfires is a relative humidity of 25 to 40% air temperature 70 to 75°F, and wind 10 mph (>8 mph). For backfires, you can use considerably cooler conditions, depending on amount of fine fuel and fine fuel moisture. We will give examples later.

In volatile fuels most firebrands ignite on punky wood, a cow chip, or lodge in a crack of bark, wood, or a tight clump of grass. Punky wood and cow chips are by far the greatest concern. Your best defense is high humidity and a wide fireline. For example, we have never seen a glowing ember start a fire when the relative humidity was above 50%. Below a relative humidity of 20%, spot fires are numerous. Thus, we prefer to burn on the high side of the 20 to 40% range to minimize danger from firebrands. If you burn with a relative humidity above 40%, consumption of dead material, particularly standing material, will be reduced considerably.

Low wind speeds (below 6 mph) also reduce the risk of glowing firebrands starting spot fires. But unless prescribed burning wind speeds are above 8 mph in grasslands, woody material will not ignite easily, and if ignited, may go out. Again, this is most applicable for standing material.

Relative humidity is related to temperature, but we have had a tendency to rely more heavily on relative humidity than temperature. However, 67°F seems to be a threshold value. Below this temperature we usually get poor burns on woody materials. Above 75°F we must be very careful; we don't recommend burning when the air temperature is above 80°F.

Every fire is different and there is always a need for some experience in a fuel type before a person feels comfortable. When you are inexperienced in a vegetation type, seek out the best information available for that type of vegetation. Start small and start under less than ideal conditions--50 to 60% relative humidity, no wind, air temperature of 50 to 60°F. Burn in late afternoon or early evening when you know the relative humidity is on the rise. Start a few small experimental burns; learn something about fire behavior, and what will burn. Document weather and fuel moisture for each burn.

Mixed Prairie with Honey Mesquite (low volatile fuel)

Detailed prescriptions for conducting burns in low volatile (mesquite-tobosagrass) and high volatile (ashe juniper) fuels have been given by Wright (1974). Depending on the objectives, a wide variety of prescriptions can be used and experience is always the best teacher. For example, if you want to clean up chained debris in buffalograss (Buchloe dactyloides) that has 2,000 lb/acre of fine fuel, burn out a 100 ft fireline on the north and east sides when the relative humidity is 30 to 50%, wind is 5 to 10 mph, and air temperature is 60 to 75°F. Burn the rest of the pasture with a headfire when the relative humidity is 20 to 40%, wind is out of the southwest at 8 to 15 mph, and air temperature is 70 to 75°F.

If dead mesquite is standing and you wish to burn it down, you need a minimum of 4,000 lb/acre of fine fuel, relative humidity below 40%, and wind in excess of 8 mph. Burn out a 100 ft fireline on the north and east sides with the relative humidity is 50 to 60% and the wind is less than 8 mph. Headfire the rest of the pasture with a southwest wind when the relative humidity is 25 to 40%, wind is 8 to 15 mph, and air temperature is 70 to 75°F.

The primary dangers in burning grasslands come from tumbleweeds and firewhirls. Tumbleweeds will ignite and then tumble, leaving flames in their path. Firewhirls develop where wind shears occur, such as when a headfire runs into a backfire, or a fire goes up slope into a wind. We have seen several firewhirls develop when headfires met backfires while winds were 10 to 15 mph. We have also seen two huge firewhirls develop when winds were light and variable. For these reasons, we prefer to burn with a steady wind and never burn into backfires, unless we have at least a 300 ft fireline. Burning should be done parallel to ridges, not across them.

Mixed Prairie with Juniper (volatile fuel)

For chained or piles of dead juniper, firebrands are a serious problem. Plan on burning out a 400 ft fireline on the north and east sides of a pasture. Burn out the dead piles of brush when the grass is green (May to early June), when the wind is less than 10 mph, and when the relative humidity is above 45%. Later (January and February), burn out the bluestem grass in the firelines when the relative humidity is 50 to 60% and the wind is less than 8 mph. Non-flaming firebrands are rarely a problem when the relative humidity is above 50% (Bunting and Wright, 1974). Where buffalograss occurs you will need more wind and less humidity.

After the fireline is burned out, burn the rest of the area with a southwest wind when the relative humidity is 25 to 40%, wind is 8 to 15 mph, and air temperature is 65 to 75°F. If there has been a recent rain, wait to burn for at least 5 days after the rain.

For safety, avoid burning backfires into headfires and don't burn across ridges. Firewhirls can easily develop. In highly volatile fuel, burn into heavily grazed pastures, when possible, to minimize risk. No person should be given prescribed burning responsibilities in this fuel type at the operational level with less than two seasons of burning experience.

To burn grasslands with young, green juniper trees (2 to 5 ft tall), one can use much smaller firelines--about 50 ft. In these case we usually cut a 10 ft fireline around the entire pasture. Then burn out 50 ft on the lee sides in late evening or early morning and put the fire out on the windward side with a pumper.

Sand Shin Oak with Little Bluestem (moderately volatile)

Burning techniques for this type in Oklahoma have not been documented. Generally there is enough grass so that the fire can back through the shinnery under cool conditions (i.e., relative humidity 50 to 60%, air temperature 60°F, and wind 5 to 10 mph). In many cases the fire would go out as it backs up. After a 200 to 300 ft fireline has been burned, the area could be headfired.

Refinement of technique is needed in this fuel type. Oak leaves are good firebrands, so one has to be reasonably careful. However, based on our experience, we have never had trouble with oak leaves beyond 50 ft. We suspect that a 200 ft fireline would be adequate to use headfires when the relative humidity is 25 to 40%, wind 5 to 10 mph, and air temperature 70 to 75°F. With 2,000 to 4,000 lb/acre of fine fuel, cooler conditions would give satisfactory burns. Based on volatile fuel data, the firelines should be burned when the relative humidity is above 50%, wind less than 8 mph, and air temperature is 45 to 65°F. The high humidity would be especially important to minimize danger from firebrands.

Firelines should be cut around the area to be burned, but the inside of the 200 ft strips could be natural breaks. Often the fire will go out when backing up and a pumper could be used to put out the spots that continue to burn.

Tallgrass Prairie

In the tallgrass prairie, particularly the Flint Hills region, many ranchers in the area have been burning for years and know how to burn. Thus, there has been essentially no need to document prescriptions for the kind of burning that they do.

Dr. Clinton Owensby in the Department of Agronomy, Kansas State University, Manhattan, Kansas is preparing a bulletin that contains prescription guidelines. He said that they don't have firebrand problems, except for some areas with red cedar, and their humidity is almost always 50 to 60% so that burning is pretty safe. Fine fuel is continuous and may be as much as 3,000 to 4,000 lb/acre.

They begin burning on the leeward sides of a pasture and initially let the fire back into the pasture. Concurrently they use two spray rigs to patrol and lay down a wet line when necessary. Usually they can backfire off a trail or road. They rarely plow permanent firelines. After the fire has backed up 100 to 150 ft,

they headfire the rest of the pasture. Headfires are conducted with 5 to 10 mph winds if improvement of forage quality is their only concern. Where brush control is important, they use winds from 5 to 15 mph and try to burn when the relative humidity is around 40%. Temperature is not a consideration for burning, but generally varies from 60 to 75°F.

Where red cedar is a problem and they want to burn tall trees, they usually rest the pasture to be assured of 3,000 to 4,000 lb/acre of fine fuel. Then they burn out a 100 to 200 ft fireline either late in the evening or early in the morning when some dew is on the grass. After the fireline has been burned, they use a headfire with winds up to 15 mph and low humidity (40% or so). Buckbrush has not given them any firebrand problems, so no special preparations are made when this shrub is present.

Marsh burns

Marsh burns are usually conducted to thin out density of reeds, create new feeding areas, and to create more edge effect for nesting areas. In the north-central Nebraska Sand Hills, Schlichtemeier (1967) found that thick, dense stands of marsh could easily be burned with excellent results after the thickness of ice was 9 to 12 inches and 2 to 4 inches of snow had fallen on the surrounding range. He conducted four burns in January and February under the following conditions:

<u>Burn No.</u>	<u>Relative humidity (%)</u>	<u>Temperature (°F)</u>	<u>Wind (mph)</u>
1	72	30	15
2	60	37	7
3	67	17	23
4	52	42	17

Combustibility of vegetation varied only slightly on all four burns. Density of reed (Phragmites communis) and bullrush (Scirpus sp.) decreased 85 to 60%.

Notice that he conducted successful burns in freezing weather which we cannot do in light or moderate grass fuels. This is primarily because of the large quantity of dry material in thick layers that is partially insulated from the prevailing weather conditions.

Northern Great Plains and Aspen Parkland (low and moderately volatile fuels)

Western snowberry, willows, and dead aspen are volatile fuels and give off abundant firebrands. These firebrands ignite dung piles causing spot fires. This occurs most frequently when the relative humidity is below 40%. Consequently, grasslands that have few shrubs or trees are usually comparatively safe to burn.

Snow is an advantage to spring burning programs in mesic areas of the Northern Great Plains. Grasslands melt free from snow several weeks before it has left the adjacent shrublands and forest. Grasslands can then be burned within a few days after snowmelt with the wet forest and shrublands or a plowed line 12 to 14 ft wide across as a fireline. Several weeks later the green grassland is an effective fireline when the shrublands and forest are burned.

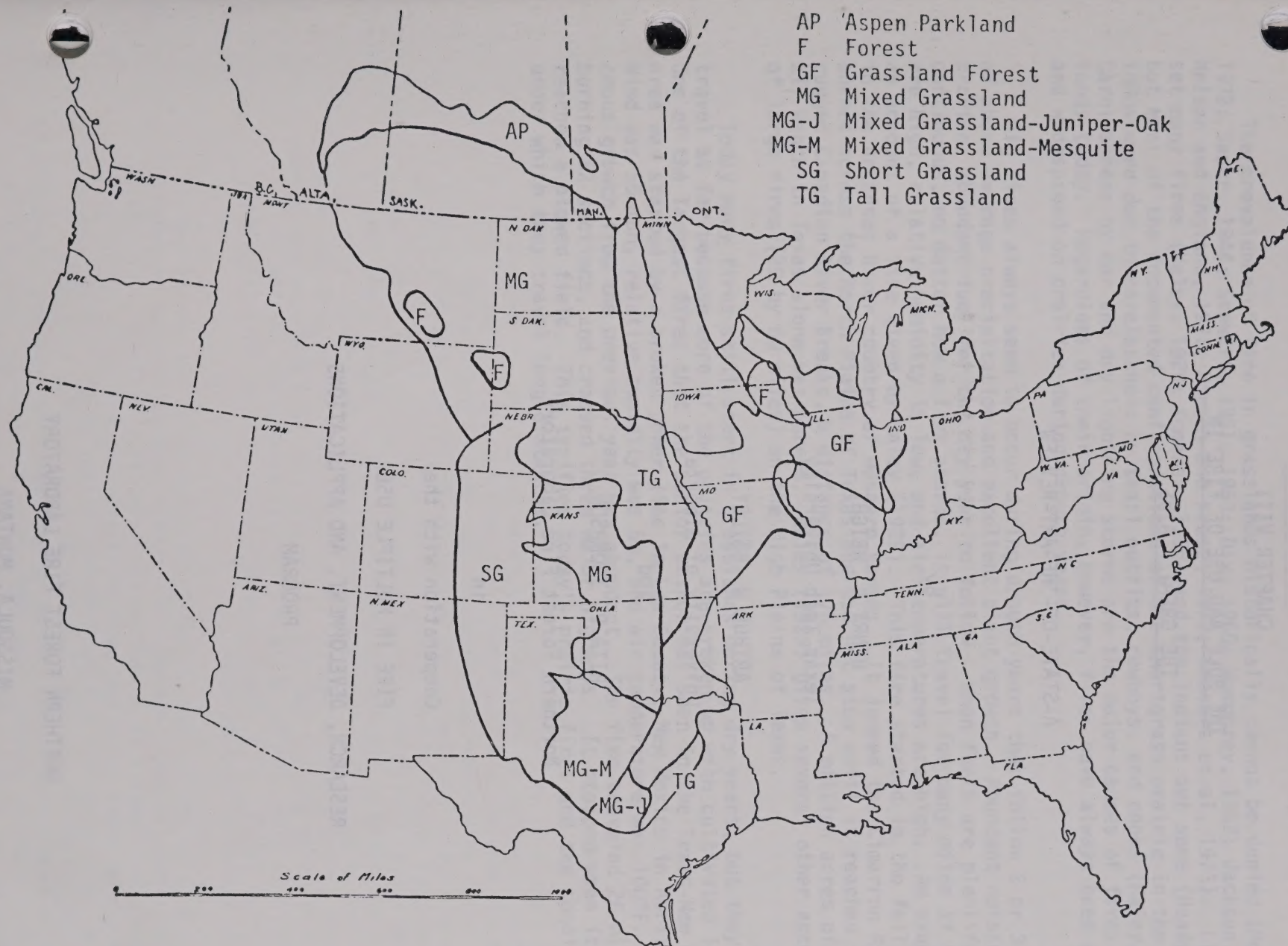
The weather conditions required for comparatively safe burning in the Alberta aspen parkland are presented in Table 1. The aspen forest and snowberry shrublands have been successfully burned only with headfires. The prescription for grass fires will need to be altered as fine fuel decreases. For example, if you were to burn blue grama, the relative humidity may need to be as low as 25 to 40%, wind 8 to 12 mph, and air temperature 50 to 70°F. A few small test burns will help one determine the desired range of weather conditions.

Table 1. Weather Conditions Required for Successful Spring Burning in the Central Alberta Aspen Parkland.

Vegetation Type	Minimum Temperature °F	Wind Speed mph	Maximum Relative Humidity %	Required Number of Drying Days
Fescue grassland	45	2-12	65	1
Snowberry shrubland	55	2-12	50	4
Aspen forest <u>1/</u>	59	4-12	40	10
Aspen forest <u>2/</u>	64	8-12	30	14

1/ There will be few spot fires but only 25 to 50% of the forest will be burned if conducted when relative humidity is 30 to 40%.

2/ Spot fires will be numerous requiring a 400 ft fireline downwind but 80 to 100% of the forest will burn if conducted when relative humidity is 10 to 30%.



Map of Natural Vegetation of Great Plains Grasslands from Kuchler (1965).

CHAPTER VIII
THE ROLE AND USE OF FIRE IN
THE GREAT PLAINS

A-STATE-OF-THE-ART-REVIEW

by

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in

Cooperation with the

FIRE IN MULTIPLE USE

RESEARCH, DEVELOPMENT, AND APPLICATIONS

PROGRAM

NORTHERN FOREST FIRE LABORATORY

MISSOULA, MONTANA

Introduction

The prevalence of fire in grasslands historically cannot be denied (Moss, 1932; Sauer, 1944; Stewart, 1951, 1953; Dix, 1960; Humphrey, 1962; Jackson, 1965; Nelson and England, 1971; Kirsch and Kruse, 1972; Seevers et al, 1973). Lightning set many fires (Haley, 1929; Komarek, 1966) and the Indians set some (Heady, 1972), but most of the documented conflagrations of the shortgrass prairie in the late 1880s were due to carelessness by trail outfits, cowboys, and cooks (Haley, 1929). Carelessness by man and dry lightning storms are the major causes of fires in grasslands today. Regardless of their origin, however, fires have always been common and widespread on prairies during drouth years.

Big fires always seem to occur during drouth years that follow 2 or 3 years of above average precipitation and excellent plant growth. Abundant moisture provides abundant fuel for the dry year to follow. When fuels are plentiful and continuous, no matter how a fire starts, it will travel for many miles if the winds are high, relative humidity is low, and air temperatures are high. An example is an account of a fire given by Haley (1929). This fire started in the fall of 1885 in the Arkansas River country of western Kansas. It jumped the Cimarron River, burned across the North Plains of Texas and did not stop until it reached the rugged Canadian River Breaks, a distance of 175 miles. A million acres of the XIT Ranch in Texas alone was burned. Haley (1929) gives several other accounts of large fires (20 by 60 miles) on the High Plains of Texas.

Today many fires still start in grasslands during dry years, but they don't travel as far because more of the prairies are broken up with cultivated land. One of the largest fires that the senior author has seen in the Texas-New Mexico area was started by a broken power line in Lea County, New Mexico in April 1974. Wind was 55 mph, relative humidity was 5%, and air temperature was 100°F. Herbaceous growth from the previous year was abundant. The fire traveled 26 miles, burning 52 sections, and crossed three major highways. It stopped when it reached a plowed field. This typifies today's prairie fires and the conditions under which they travel long distances.

Fire History of the Prairie Grasslands

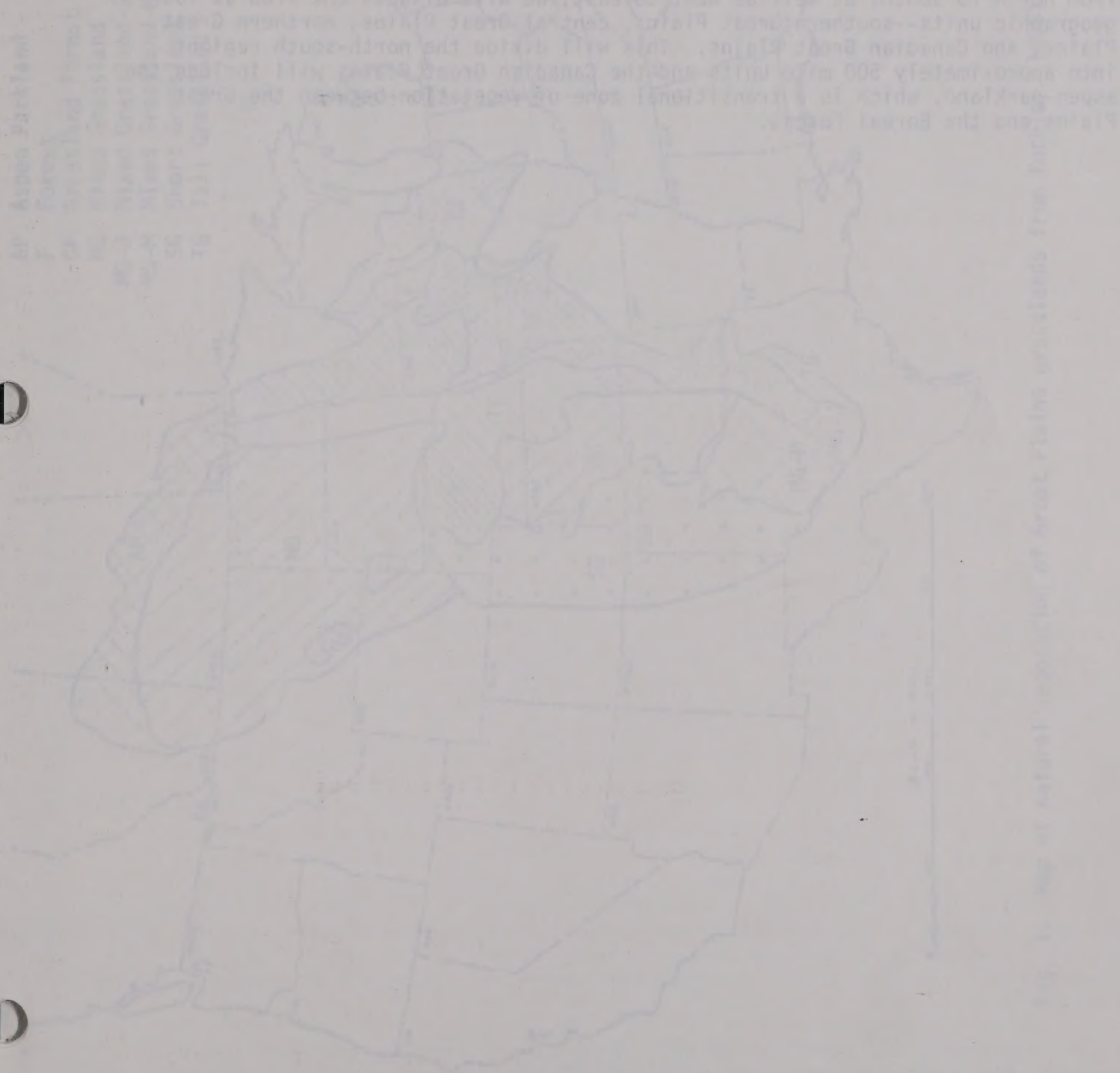
Since prairies do not have trees that can tolerate a series of fires and retain fire scars, this type of historical record for fires in grasslands is not available. The only thing we know for sure is that fires occurred, and explorers and settlers were always concerned about the danger of prairie fires. We can extrapolate some fire frequency data from forests with grassland understories such as ponderosa pine (Pinus ponderosa) forests in the West and pine forests in the Southeast. A variety of sources (Weaver, 1951; Wagener, 1961; Hall, 1976; Arno, 1976; Chapman, 1926; Chapman, 1944) indicate that the fire frequency in pine forests varies from 2 to 25 years. Thus, in the level to rolling topography of prairie grassland it seems reasonable that before the advent of white man a natural fire frequency could have been 5 to 10 years. In rough topography that is dissected with breaks and rivers such as the Rolling Plains and Edwards Plateau of Texas, fire frequency may have been 20 to 30 years. This latter statement is based largely on historical documents of large mesquite trees in the Rolling Plains by Marcy (1849) and the frequency of fire that would be necessary to keep large ashe juniper trees (Juniperus ashei) out of prairies in the Edwards Plateau.

A question that usually arises is how important have historic fires been in maintaining grasslands? Stewart (1951, 1953) and Sauer (1944) have proposed that treeless grasslands are a product of repeated fires set by aborigines. Wedel (1957) and Hastings and Turner (1966) make a strong case for climate as being the primary factor that characterizes American grasslands; winter rainfall decreases rapidly from the Southeast to the center of the United States and winter snowfall decreases rapidly from the eastern edge of the Rockies to the Southwest and across the northern margin in the Great Plains, making this area unsuitable for tree growth (Wedel, 1957). Wells (1970) shows evidence that the origin and maintenance of grasslands is directly related to topography. He states that the "rougher and more dissected the topography, the greater the former extent and the current spread of woody vegetation at the expense of grasslands."

Based on our experience and knowledge of previous research, climate is the dominant factor that characterizes the North American grasslands, although wide fluctuations in woody vegetation would occur if it were the only factor. The impact of drouth in the maintenance of grasslands has been illustrated by Albertson and Weaver (1945). Following the drouth of the 1930s, they surveyed the mortality of natural trees, timber belts, old shelterbelts, and hedgerows from Oklahoma to Nebraska. Their studies of native trees showed mortality rates ranging from 30 to 93% among the deciduous trees (elm, ash, hackberry) and from 35 to 80%, or higher, among juniper. On the eastern edge of the Great Plains "the balance between forest and grassland is so delicate that a little higher water content of soil, a slightly greater humidity, or protection from drying winds throws this balance in favor to tree growth, while the reverse conditions exclude it" (Albertson and Weaver, 1945). Thus there is good reason to think that climate is the major factor in maintaining grasslands.

Nevertheless, data in the Southern Mixed Prairie indicate that drouth (not necessarily severe), fire, insects, rodents, and competition from grass on level to undulating topography interact as a unit to characterize grasslands. In 1969 we burned 1,200 mesquite trees which had been previously top-killed by spray in 1966, and killed 26.4% of them over a 5 year period (Wright et al, 1976a). We attribute part of the mortality to fire, but over half of it (due to a mild drouth in 1970 and a severe one in 1971) seems to have resulted from the interaction between fire, drouth, insects, rodents, and competition from grass. Thus, a fire every 15 to 30 years in the Southern Mixed Prairie could have a significant effect on the reduction of shrubs.

In general, shrubs and trees have always existed on grasslands. In the Great Plains they are most abundant in the Southern Mixed Prairie, eastern edge of the tallgrass prairie, and rocky breaks or heavily grazed areas where fires are the least frequent. Drouths can control the abundance of shrubs where grass is healthy, but the shifts from grasslands to shrubs and trees may occur on a 100-year cycle if the climate is the only factor. With fire as a factor, as it seems to have been in the past, shrub and tree growth is restricted (Malin, 1953) because fire triggers a significant interaction with other factors.



Ecological Characteristics and Effects of Fire on

Great Plains Prairie Communities

The North American Grassland is a vast area that lies between the Rocky Mountains and the western boundary of the Oak-Hickory Forest and extends from south-central Texas to the aspen-parkland in central Alberta and Saskatchewan (Fig. 1). Often the area is divided from west to east into the shortgrass, mixed, and tallgrass prairies and grassland-forest combinations (Launchbaugh, 1972). However, since there is such a wide variation in species combinations from north to south, as well as west to east, we will discuss the area as four geographic units--southern Great Plains, central Great Plains, northern Great Plains, and Canadian Great Plains. This will divide the north-south regions into approximately 500 mile units and the Canadian Great Plains will include the aspen-parkland, which is a transitional zone of vegetation between the Great Plains and the Boreal Forest.

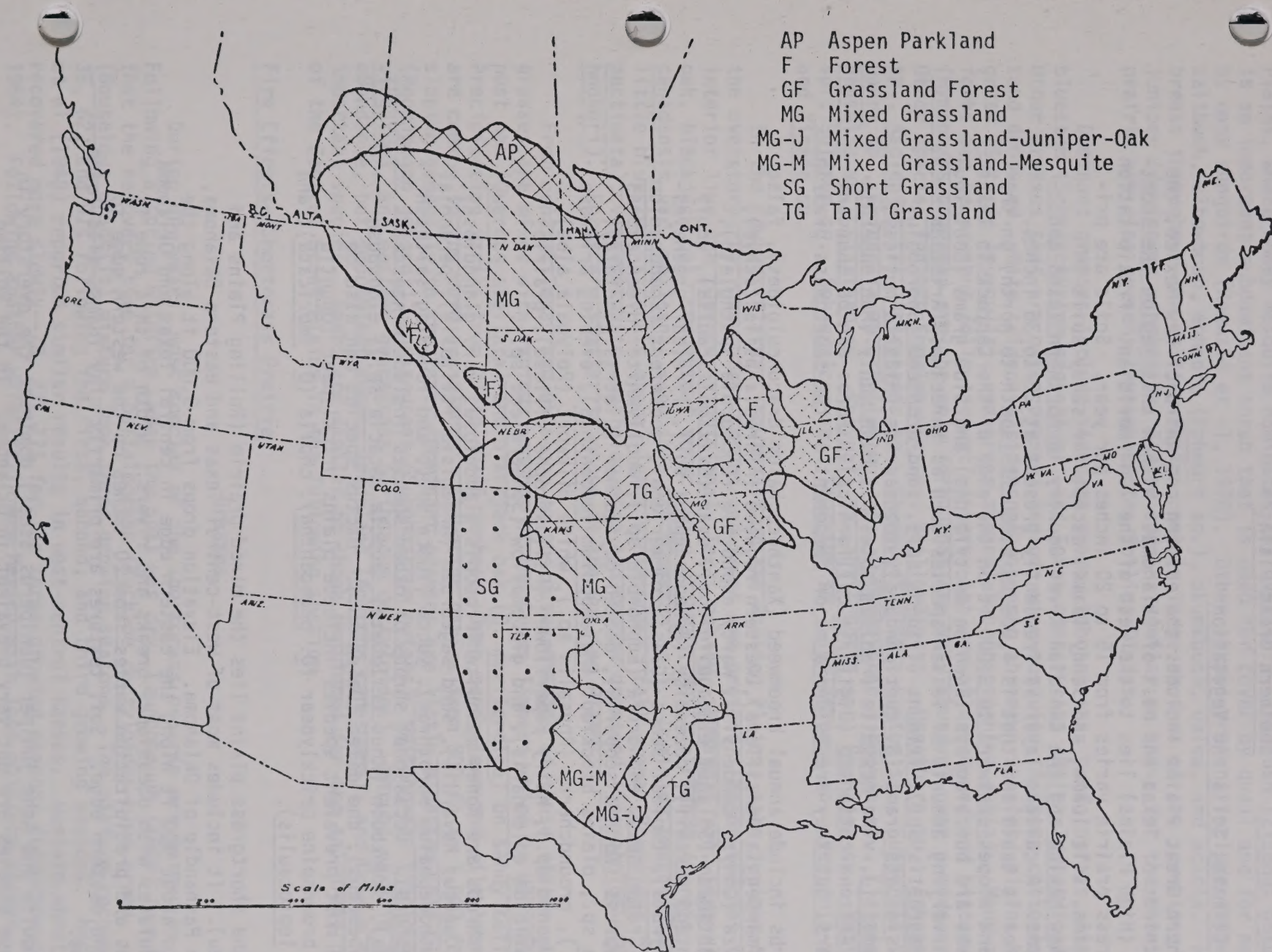


Fig. 1. Map of natural vegetation of Great Plains grasslands from Kuchler (1965).

Southern Great Plains

Distribution, Climate, Soils and Vegetation

The southern Great Plains includes the eastern one-third of New Mexico, the northern two-thirds of Texas and most of Oklahoma. Within this region the shortgrass prairie (High Plains) lies to the west of the 100° meridian. Precipitation in the shortgrass prairie varies from 15 to 20 inches per year. Soils are primarily clay loams, silt loams, and sandy loams, except for sandy soils in southeastern New Mexico and the Canadian River Country in northern Texas and western Oklahoma. A caliche layer is frequently present at 20 to 36 inches. Most of the area is tableland that is 4,000 to 6,000 ft (south to north) on the western edge and slopes eastward to 3,000 ft on the edge of the Caprock in Texas. Dominant grasses are buffalograss (Buchloe dactyloides) and blue grama (Bouteloua gracilis) with varying amounts of lesser species such as threeawns (Aristida sp.), eragrostis (Eragrostis sp.), tridens (Tridens sp.), sand dropseed (Sporobolus cryptandrus), sideoats grama (B. curtipendula), tobosagrass (Hilaria mutica), galleta (H. jamesii), vine-mesquite (Panicum obtusum), bush muhly (Muhlenbergia porteri), and Arizona cottontop (Digitaria californica). Forbs can be abundant during wet years, but they are seldom a major component of the shortgrass prairie.

Major forbs include annual broomweed (Xanthocephalum dracunculoides), false mesquite (Hoffmanseggia densiflora), western ragweed (Ambrosia psilostachya), horsetail conyza (Conyza canadensis), warty euphorbia (Euphorbia spathulata), silverleaf nightshade (Solanum elaeagnifolium), evax (Evax multicaulis), wooly plantago (Plantago purshii), dozedaisy (Aphanostephus sp.), lyreleaf greeneyes (Berlandiera lyrata), twoleaf senna (Cassia roemeriana), goosefoot (Chenopodium sp.), croton (Croton sp.), euphorbia (Euphorbia sp.), woollywhite (Hymenopappas sp.), summercypress (Kochia scoparia), dotted gayfeather (Liatris punctata), Machaeranthera sp., plains blackfoot (Melampodium leucanthus), evening primrose (Denothera sp.), groundcherry (Physalis sp.), white milkwort (Polygala alba), knotweed (Polygonum sp.), hairy paperflower (Psilostrophe villosa), prairie coneflower (Ratibida columnaris), and globemallow (Sphaeralcea sp.).

Dominant shrubs are honey mesquite (Prosopis glandulosa) var. glandulosa), shinnery oak (Quercus havardii), sand sagebrush (Artemisia filifolia), perennial broomweed (Xanthocephalum sarothrae), yucca (Yucca sp.), and fourwing saltbush (Atriplex canescens). Occasional shrubs of other species include winterfat (Eurotia lanata), skunkbush (Rhus trilobata), acacia (Acacia sp.), elbowbush (Foresteria pubescens), and dalea (Dalea sp.). Cactus species can also be abundant. The most prevalent species include plains pricklypear (Opuntia polyacantha), brownspine pricklypear (O. phaeacantha), cholla (O. imbricata), and tasajillo (O. leptocaulis).

East of the shortgrass plains lies the mixed prairie (Rolling Plains and Edwards Plateau). It includes most of west-central Texas and eastern Oklahoma, except for the Panhandle of Oklahoma. Elevation drops from 3,000 ft along the western edge to about 900 ft along the eastern edge in central Texas and Oklahoma. Topography undulates with occasional breaks and rivers. Width of this zone is about 150 miles and precipitation varies from 20 inches on the western edge to 28 inches on the eastern edge. Soil textures are primarily clay loams, silt loams, and sandy loams.

Honey mesquite and Ashe juniper (Juniperus ashei) dominate the overstory in Texas, but these species are not very prevalent in Oklahoma. In the Rolling

Plains, where honey mesquite dominates the overstory, lotebush (Zizphus obtusifolia) is an important subdominant shrub that is used for cover by quail and for nesting by many songbirds (Renwald et al, 1978). Other shrubs present include fourwing saltbush, elbowbush, ephedra (Ephedra sp.), skunkbush, dalea, and acacia. However, breaks throughout the Rolling Plains contain large amounts of the sprouting redberry juniper (Juniperus pinchoti). Cactus species similar to those for the shortgrass prairie are also present throughout the Rolling Plains.

Dominant grasses include sideoats grama, tobosagrass, buffalograss, little bluestem (Schizachyrium scoparium), and Texas wintergrass (Stipa leucotrica). Other grasses that are often present include vine-mesquite, Arizona cottontop, sand dropseed, white tridens (Tridens albescens), threeawn species, plains bristlegrass (Setaria leucopila), and green sprangletop (Leptochloa dubia). Many annual forbs can be present following wet winters, but annual broomweed and bitterweed (Hymenoxys odorata) are the only forbs that are very abundant over a wide area. Other species include Engelmannia sp., Gaillardia sp., Oenothera sp., Aphanostephus sp., Asclepias sp., Astragalus sp., Chenopodium sp., Croton sp., Euphorbia sp., Gaura sp., Grindelia sp., Helianthus sp., Hymenoxys sp., Kochia sp., Liatris sp., Physalis sp., Plantago sp., Polygala sp., Prionopsis sp., Psoralea sp., Ratibida sp., Solanum sp., Sphaeralcea sp., Teucrium sp., Thelosperma sp., Vernonia sp., and Zinnia sp.

In the Edwards Plateau, southeast of the Rolling Plains, ashe juniper dominates the overstory, but many other shrubs and trees are present. Major species include interior live oak (Quercus virginiana), Texas oak (Q. shumardii var. texana), post oak, blackjack oak, smoothleaf sumac (Rhus glabra), Mexican redbud (Cercis canadensis var. mexicana), and shin oak (Quercus sp.). Dominant grasses include little bluestem, sideoats grama, Texas wintergrass, tall grama (Bouteloua pectinata), vine-mesquite, buffalograss, and meadow dropseed (Sporobolus asper var. hookeri). Forbs are similar to those in the Rolling Plains.

From central Texas and Oklahoma to the eastern edges of these states, tall grasses are mixed with various amounts of the Cross Timbers which is dominated by post oak (Quercus stellata) and blackjack oak (Q. marilandica) on sandy soil. Precipitation varies from 27 to 40-45 inches. Deep sandy loam and silt loam soils are common in the pure grasslands. Elevation varies from 500 ft to 1,000 ft, sloping generally to the East. Dominant grasses are little bluestem, big bluestem (Andropogon gerardi), Indiangrass (Sorghastrum nutans), switchgrass (Panicum virgatum), and eastern gramagrass (Tripsacum dactyloides). Shrubs vary in their abundance, but smoothleaf sumac, leadplant (Amorpha canescens), and Prunus sp. are important species. Forbs are similar to those mentioned for the tallgrass prairie of the Central Great Plains in the following section.

Fire Effects--Shortgrass Prairie

Grasses

During dry years, most species of the shortgrass prairie are harmed by fire. Following a spring wildfire, when the soil was dry, Launchbaugh (1964) found that the recovery time for a buffalograss (Buchloe dactyloides-blue grama (Bouteloua gracilis) mixture took three growing seasons. The mixture recovered 35, 62, and 97% following the first, second, and third growing seasons. Hopkins et al (1948) reported similar results in west-central Kansas. Western wheatgrass recovered more slowly--18, 27, 77% for the three growing seasons (Launchbaugh, 1964). Following another wildfire in New Mexico with less moisture stress,

Dwyer and Pieper (1967) found that the production of blue grama was reduced 30% the first year. With above average precipitation the second year after burning, blue grama was 97% recovered. Prescribed burns in Texas during years with above normal winter and spring precipitation show that buffalograss and blue grama can tolerate fire very well with no loss in herbage yield at the end of the first growing season (Trlica and Schuster, 1969; Heirman and Wright, 1973; Wright, 1974) (Table 1).

The tolerance of most grass species to fire in the shortgrass prairie under different moisture regimes seems to be similar to that for buffalograss and blue grama. Red threeawn (Aristida longiseta) and sand dropseed (Sporobolus cryptandrus) are generally harmed by fire (Hopkins et al, 1948; Dwyer and Pieper, 1967; Trlica and Schuster, 1969). By contrast, Wright (1974) found that sand dropseed tolerated fire very well when winter and spring precipitation was 40% above normal. Other species that Dwyer and Pieper found to be harmed by fire included slim-stemmed muhly (Muhlenbergia filiculmis), ring muhly (M. torreyi), wolf-tail (Lycurus phleoides), and Galleta (Hilaria jamesii). However, this latter data is based on a wildfire during a year when precipitation was below average. Tumble windmill grass (Schedonnardus paniculatus) was not harmed by fire (Trlica and Schuster, 1969). Weeping lovegrass (Eragrostis curvula, an introduced species, is increased 14% by burning, but the biggest benefit from fire is a 53% increase in utilization (Klett et al, 1971).

In the southern shortgrass Plains sandy lands are common among the heavy clay soils that are dominated by buffalograss and blue grama. The sandy soils are dominated by sand bluestem (Andropogon hallii), little bluestem (Schizachyrium scoparium), switchgrass (Panicum virgatum) and shinnery oak (Quercus havardii). Burning generally increases production of sand bluestem and switchgrass about 300 lb/acre and similarly decreases production of little bluestem with a net increase in total forage of 20% (McIlvain and Armstrong, 1968).

Forbs

Grasses provide the major portion of prairie vegetation, but frequently forbs occur in endless numbers of species and individuals particularly during wet years. Heirman and Wright (1973) found that spring burning was detrimental to many forms: annual broomweed (Xanthocephalum dracunculoides), silverleaf nightshade (Solanum elaeagnifolium), western ragweed (Ambrosia psilostachya), and horsetail (Conyza canadensis). Warty euphorbia (Euphorbia spathulata), rabbit's tobacco (Evax multicaulis), and woolly plantago (Plantago purshii) were not affected, and false mesquite (Hoffmanseggia densiflora) was favored by spring burning.

Total forb yields are usually decreased more by spring burns than fall burns (Hopkins et al, 1948). In all cases, however, forb composition will be altered the least by burning when plants are dormant. Young, active growing forbs will be severely harmed by fire.

Shrubs

The shortgrass prairie does not have many shrubs except in the southern mixed prairie where shrubby mesquite is present on native ranges today. However, mesquite has not always been as prevalent a shrub on the High Plains of Texas as it is currently. In the journals of Captain R. B. Marcy (1849) when he and his command traveled over the northern part of the Llano Estacado near Amarillo, Texas he gives the following description of what he saw:

Table 1. Yields (lb/acre) of Buffalograss and Blue Grama After Burning During a Series of Dry Years and a Series of Wet Years.

Year After Burn	Burned		Unburned	
	Current Growth	Litter	Current Growth	Litter
<u>Wet years</u> (Texas data)				
Buffalograss				
First (1968)	1686		1494	728
Second (1969)	2063	306	1928	458
Third (1970)	1398	1572	1330	906
Bluegrama				
First (1970)	1680		1429	2474
Second (1971)	1369	699	1247	2584
Third (1972)	2142	1750	1754	1932
<u>Dry years</u> (Kansas data) ^{1/}				
Buffalograss-Blue grama				
First (1959)	1100		3150	500
Second (1960)	1840	250	3000	500
Third (1961)	2600	330	2650	550

^{1/} Taken from Launchbaugh, 1964.

"When we were on the high tableland, a view presented itself as boundless as the ocean. Not a tree, shrub, or any other object, either animate or inanimate, relieved the dreary monotony of the prospect; it was a vast, illimitable expanse of desert prairie--the dreaded 'Llano Estacado' of New Mexico; or, in other words, the great Sahara of North America. It is a region almost as vast and trackless as the ocean--a land where no man, either savage or civilized permanently abides; it spreads forth into a treeless, desolate waste of uninhabited solitude, which always has been, and must continue, uninhabited forever; even the savages dare not venture to cross it except at two or three places, where they know water can be found. The only herbage upon these barren plains is a very short buffalo-grass, and, on account of a scarcity of water, all animals appear to shun it."

Today, honey mesquite is prevalent on the High Plains and it is almost impossible to kill it with fire (Wright et al, 1976). Even the seedlings are very tolerant to fire (Fisher, 1947). Moreover, honey mesquite on the High Plains has exceptional ability to resprout, compared to mesquite in the Rolling Plains. With this background and very few observations of honey mesquite by early explorers on the High Plains (Malin, 1953; Box, 1967), we are of the opinion that, before white man's arrival, honey mesquite had a high frequency and low cover on the High Plains. Also, because of the necessity to survive frequent fires in its past history, honey mesquite seems to be genetically adapted to fire and has vigorous sprouting ability. In a low state of growth with frequent fires it would seem that the combination of fire, drouth, competition from grasses, and damage from rodents, particularly rabbits and rats, would have a serious effect on honey mesquite and keep it at a low height.

On sandy lands in eastern New Mexico, northern Texas and western Oklahoma, shinnery oak (Quercus havardii) is abundant, although in southeastern New Mexico the sandy land is dominated by shrubby honey mesquite. Shinnery is very fire tolerant and the density of its stems increases 15% after burning (McIlvain and Armstrong, 1966). However, no acorns are formed during the year of a burn, which could affect prairie chicken and turkey populations.

In New Mexico algerita, fourwing saltbush, winterfat (Eurotia lanata), and skunkbush sumac (Rhus trilobata) resprout vigorously after fire (Dwyer and Pieper, 1967). Chickasaw plum (Prunus angustifolia) and aromatic sumac (Rhus aromatica) sprout vigorously after burning in the southern Great Plains (Jackson, 1965). In the northern Panhandle of Texas, sand sage (Artemisia filifolia) is a non-sprouter but comes back vigorously as a seedling after fire (Jackson, 1965).

Cacti seem to be quite easily killed by fire, at least over a 2 year period. Tasajillo (Opuntia leptocaulis) is easily killed by fire with 80% mortality (Bunting and Wright, 1978). Cholla (O. imbricata) and prickly-pear (O. phaeacantha) are also easily killed by fire if they are less than 1 ft high. In New Mexico Dwyer and Pieper (1967) found that chollas less than 1 ft high were reduced by 50% after burning, but cacti over 1 ft were hardly damaged. Heirman and Wright (1973) reported similar data for West Texas. This is largely because the flames in a shortgrass community are usually from 1-1/2 to 2 ft high and will engulf plants easily that are less than 1 ft high. Plants which are taller are not burned at the higher levels and thus they survive fire quite easily in the shortgrass prairie. Chaining the tall cholla plants before burning will greatly increase their mortality (Heirman and Wright, 1973).

Fire Effects--Mixed Prairie

Grasses

Most grasses of the mixed prairie tolerate fire well during normal to wet years, but sideoats grama (Bouteloua curtipendula) and Texas wintergrass (Stipa leucotrica) can be severely harmed. Sideoats grama, the rhizomatous form, is almost always reduced 40 to 50% by fire and requires 3 years for full recovery (Hopkins et al, 1948; Wright, 1974). During exceptionally wet years it tolerates fire reasonably well with only a 12% reduction in yield (Wink and Wright, 1973). Texas wintergrass is severely harmed by sweeping broadcast fires (Dahl and Goen, 1973), but increases following creeping, cool fires (Bean et al, 1975). Little bluestem (Schizachyrium scoparium) will decrease as much as 58% during dry years (Hopkins et al, 1948) or increase as much as 81% during wet years (Wink and Wright, 1973).

Tobosagrass (Hilaria mutica) is a southern desert species that is quite prevalent on bottomland sites in the southern mixed prairie. It is a highly productive species (Paulsen and Ares, 1962; Dwyer, 1972) until it accumulates large amounts of litter (Wright, 1969) that decays slowly (Weaver and Albertson, 1956). Young tobosagrass leaves are palatable, but as plants mature and accumulate litter, they become coarse and unpalatable (Herbel and Nelson, 1966; Wright, 1972; Heirman and Wright, 1973).

Burning can greatly increase the production and palatability of tobosagrass during normal to wet years (Heirman and Wright, 1973). During wet years after burning, tobosagrass will increase over 2,000 lb/acre. Over a series of dry, normal, and wet years (5 years), tobosagrass production increased an average of 1,030 lb/acre the first growing season following a burn (Wright, 1972). Total production increased over the controls for a 3 year period and then reached equilibrium during the fourth year after burning (Wright, 1972; Neuenschwander, 1976). However, in southern New Mexico where annual precipitation is only 9 inches per year, no increase in tobosagrass yields can be expected after burning (Dwyer, 1972).

Since tobosagrass is such a coarse grass, it should be grazed within a few weeks after burning. If it is rested for 3 or 4 months, as we do for most other grasses, it will be so coarse that animals will not eat it. Cattle normally like to eat this grass during the spring and fall periods when it is growing rapidly. Wright and Heirman (1973) found that tobosagrass utilization could be increased many-fold following a burn. Normally cattle eat only about 10% of the tobosagrass but following a burn they will eat as much as 66% of the tobosagrass (Heirman and Wright, 1973).

Since tobosagrass and buffalograss often grow in combination and cattle will eat tobosagrass in preference to buffalograss (Heirman and Wright, 1973), burning followed by grazing can be a means to increase the vigor of desirable grasses and in general improve the condition of the range. However, tobosagrass cannot take very heavy utilization for an extended number of years (Canfield, 1939). Fifty percent should probably be the maximum utilization of tobosagrass during any year.

As long as moisture is adequate, vine-mesquite (Panicum obtusum), Arizona cottontop (Digitaria californica), plains bristlegrass (Setaria leucopila), Texas cupgrass (Eriochloa sericia), and meadow dropseed (Sporobolus asper var.

hookeri) thrive after fire (Box et al, 1967; Wink and Wright, 1973; Wright, 1974). Tall grama (Bouteloua pectinata) also does well after burning for 2 years, whereas Arizona cottontop will show increased yields after burning for only 1 year (Wright, 1974). The bunchgrass form of sideoats grama also seems to thrive after fire (Wright, 1974).

Cool season annual grasses are severely harmed by spring burning. In the southern mixed prairie this affects primarily little barley (Hordeum pusillum) and Carolina canary grass (Phalaris caroliniana). Where these species are the only cool season grasses growing during the winter, care should be taken not to burn an entire pasture. Otherwise, there is very little green feed for animals during the winter and early spring months.

Forbs

Forbs which begin growing prior to the burning season are usually harmed by fire, and those that initiate growth after the burning season are usually not harmed by fire. In the southern mixed prairie the species that are usually harmed during the first growing season after burning include annual broomweed, mare's tail, plains dozedaisy (Aphanostephus ramossissimus), scarlet globemallow, and bitterweed. Species which are common on burns include lambsquarter (Chenopodium leptophyllum), silverleaf nightshade (Solanum elaeagnifolium), Carolina horsenettle (Solanum carolinense), and annual sunflower (Helianthus annuus). During the second growing season after burning, plains dozedaisy and redseed plantain (Plantago rhodosperma) reach their maximum importance value (Neuenschwander, 1976).

In west-central Kansas, Hopkins et al (1948) found that spring burning severely harmed wild onion (Allium nuttallii) and perennial broomweed (Xanthocephalum sarothrae), but left perennial ragweed (Ambrosia psilostachya) and goldenrod (Solidago mollis) unharmed. Launchbaugh (1964) found western ragweed and mare's tail to be somewhat harmed by spring burns, but burned plots were not significantly different from the controls.

Trees and Shrubs

The presence of mesquite (Prosopis glandulosa var. glandulosa) and other shrubs in the southern mixed prairie before the arrival of white man has been well documented in the journals of Marcy (1849) and Michler (1850). Mesquite was present throughout the entire southern mixed prairie on uplands as well as bottomlands in the Rolling Plains (mixed prairie). A map of Marcy's expedition shows vegetation marked as "mesquite timber" from Big Spring to the junction of the Clear Fork of the main Brazos River. This area was approximately 120 to 150 miles long and 50 miles wide. Throughout the rest of the Rolling Plains explorers always talked about the continuous presence of mesquite, frequently as a low-growing shrub at the northern and southern extremities.

That fire was a part of the "mesquite timber" country has also been documented. After leaving the Double Mountain Fork and the Clear Fork of the Brazos on his way to the Big Spring, Michler (1850) gave the following description:

"There was but little timber upon these streams upon first leaving the main fork, but the further we advanced the more we found, elm being the principal growth. The whole country was well timbered with mesquite, but most of it had been killed by prairie fires."

Evidently, this must have been a recent fire since Marcy and his command had traveled through the same country the previous year and did not mention the fire.

We have done a considerable amount of research on honey mesquite near Colorado City, Texas, which is in the "mesquite timber" country so designated by Marcy. Mesquite is moderately affected by fire depending upon its age, its history, weather at time of burning, and the amount of fine fuel for burning (Wright, 1972; Wright et al, 1976). Green mesquite trees are very difficult to kill with one fire unless they are very young. Young mesquite trees that were burned at temperatures above 200°F were easily killed by fire up to 1.5 years of age, severely harmed at 2.5 years of age, and very tolerant of fire after 3.5 years of age (Table 2).

Large mesquite trees that had previously been killed with 2,4,5-T were killed more easily than small trees with resprouts (Britton and Wright, 1971). This was because of the infestation with insect borer activity following the drouth of the 50s in the larger trees.

Trees previously top-killed by agents such as drouth, herbicides, etc. were moderately harmed by fire. Percent mortality of 1,200 trees that had resprouted after spraying in 1966 and were burned in 1969 was as follows:

	<u>Year</u>				
	<u>1969</u>	<u>1970</u>	<u>1971</u>	<u>1972</u>	<u>1973</u>
<u>Mortality(%)</u>	10.8	17.7	22.6	25.7	26.4

Table 2. Percent Mortality of Young Mesquite Trees After Burning in Relation to Age and Maximum Soil Surface Temperature.

<u>Age (Years)</u>	<u>Temperature (F)</u>				
	<u>200</u>	<u>500</u>	<u>800</u>	<u>1100</u>	<u>Control</u>
0.5	43	91	100	100	14
1.5	60	100	100	100	0
2.5	20	40	64	72	0
3.5	8	8	8	8	4
10 Approx.)	0	0	4	8	0

The initial mortality was caused by the ignition of dead mesquite stems which served as a fuel source to burn into living crowns. For this kind of burning to take place, winds must be in excess of 8 mph and the relative humidity must be below 40% at the time of burning. Subsequent mortalities were caused by an interaction between a weakened condition caused by fire, drouth, competition from grasses, insect damage, and damage by rabbits and rats.

Juniper species are quite common throughout the prairie country on rocky slopes such as escarpments, ridges, or rimrocks (Wells, 1970) as well as on areas that have been protected from fire (Penfound, 1964). Arend (1950) found that in Oklahoma fire was the worst natural enemy of eastern red-cedar (Juniperus virginiana), a non-sprouting species. Similarly Dalrymple (1969) and Wink and Wright (1973) have found ashe juniper (J. ashei), another non-sprouting species, also very susceptible to fire in southern Oklahoma and central Texas. These species cannot maintain themselves in areas that burn frequently because the leaves are very flammable, especially during fall months, and the bark is so thin that heat from one surface fire usually kills all trees.

With 500 to 1,000 lb/acre of herbaceous fuel, Dalrymple (1969) obtained a 100% mortality of trees less than 2 ft tall, 77% mortality of trees 2 to 6 ft tall, and 27% mortality of trees over 6 ft tall, for an average mortality of 68%. Where fine fuel was at least 1,100 lb/acre, Wink and Wright (1973) found that 99% of the ashe juniper trees less than 6 ft tall were killed by fire with the following weather conditions: air temperature 75 to 85°F, relative humidity 25 to 35%, wind 10 to 15 mph. If fine fuel was above 2,500 lb/acre, all juniper trees were killed by fire. With 750 lb/acre of fine fuel Dwyer and Pieper (1967) reported that 70% of the juniper trees exposed to high temperatures of a summer wildfire, eventually died by the following year.

Redberry juniper (J. pinchoti), a sprouting species on rough breaks in the Rolling Plains, is very difficult to kill by fire unless the trees are under 12 years of age (Smith et al, 1975). However, fires reduce the sphere of influence of the trees. Once a tree is established, it dominates the area around it and very little forage grows under the tree. When the trees are burned, they dominate less area, and grasses and forbs encroach.

Several shrub species are present in the mixed prairie of the southern Great Plains, but they are less abundant than the tree species. One palatable species that thrives after fires is fourwing saltbush. It is a vigorous sprouter and appears to have fully recovered 3 years after a burn. In mesquite communities lotebush also sprouts after a fire, but regains its original position in a community about 6 years after a burn. Littleleaf sumac (Rhus microfilia) and algerita (Berberis trifoliata) sprout following fires, but we have relatively little research data on these species in West Texas. Smoothleaf sumac and all species of oak are vigorous sprouters in ashe juniper communities of the Edwards Plateau.

Cacti are frequently present in high densities in mesquite-tobosa communities, but they are not well adapted to fire. Tasajillo (Opuntia leptocaulis) is easily killed by fire with 70 to 80% mortality (Bunting and Wright, 1978). Pricklypear (Opuntia phaeacantha) and walkingstick cholla (Opuntia imbricata) are also severely harmed by fire (Heirman and Wright, 1973; Bunting and Wright, 1978). All mortality of cactus species is the result of a fire-insect interaction, and frequently, animals (domestic and wild) also have an impact.

Fire Effects--Mixed Tallgrass--Forest

In east-central Texas and eastern Oklahoma the cross timbers occupy a sandy belt of land that contains post oak and blackjack oak as well as many tallgrass prairie species, particularly little bluestem, in the understory. Both oak species are easily top-killed by fire but resprout vigorously. No fire research has been done in this area and it is not clear as to what the natural role of fire may have been. Presently there is a lot of interest in the possibility of using fire on a 4-year rotation to keep the sprouts of oak suppressed, since it is no longer economical to use goats or chemicals for this purpose in bluestem pastures.

Central Great Plains

Distribution, Climate, Soils, and Vegetation

The Central Great Plains extend from the foothills of the Rockies in eastern Colorado and southeastern Wyoming eastward through Kansas and Nebraska to grassland-forest combinations in northwest Missouri, southern Iowa, and Illinois. Shortgrass prairie lies primarily in eastern Colorado, but it is also found in western Kansas, southeastern Wyoming, and the extreme portion of western Nebraska. Precipitation varies from 11 to 18 inches per year. Surface soil textures are largely sand, sandy loam, loamy sand, loam and silt loam. Elevation drops from 5,000 or 6,000 ft along the foothills in Colorado to 3,000 ft on the eastern edge of the shortgrass prairie in Kansas. In Nebraska the eastern elevations vary from 4,000 to 5,000 ft.

Dominant grasses on the sandy textured soils are blue grama, prairie sandreed (Calamovilfa longifolia), and needle-and-thread (Stipa comata). Other grasses include sun sedge (Carex heliophyla), red threeawn (Aristida longiseta), and sand dropseed (Sporobolus cryptandrus). Well managed ranges in eastern Colorado can also support sand bluestem (Andropogon halli), switchgrass (Panicum virgatum), and Indiangrass (Sorghastrum nutans). Dominant forbs and shrubs are western ragweed (Ambrosia psyllostachya), bush morning glory (Ipomea leptophila), herbaceous sage (Artemisia ludoviciana), and fourwing saltbush.

On loams and silt loams buffalograss, blue grama, western wheatgrass, and scarlet globemallow are the dominants. Ranges in good to excellent condition will also contain green needlegrass (Stipa viridula).

East of the shortgrass prairie lies tallgrass prairie in the Sand Hills of northwestern Nebraska and mixed prairie in the remainder of western Nebraska and Kansas. Elevation along the western edge of the mixed prairie in Kansas is 3,000 ft but rises to as much as 5,000 ft along the western edge of the Sand Hills in Nebraska. Along the eastern edge elevation starts at 1,300 ft in southern Kansas and rises to as much as 2,000 ft in north-central Nebraska. Precipitation varies from 18 to 28 inches in Kansas and 18 to 23 or 25 inches in Nebraska. Topography varies from undulating to rolling ridgetops, gently sloping, and hilly with steeply sloping valley sides. Soil textures are sand, silt, loam, silt loam, silty clay loam, and clay uplands.

Dominant grasses in the mixed prairie of the Central Great Plains are blue grama, little bluestem, sand dropseed, tall dropseed (Sporobolus asper), western wheatgrass, buffalograss, sideoats grama, purple threeawn (Aristida purpurea), needle-and-thread, junegrass (Koeleria cristata), and occasional plants of sand bluestem, prairie sandreed, and switchgrass. Western wheatgrass and needle-and-thread become more prevalent as you go northward from Kansas into Nebraska. Common forbs include scarlet globemallow, western ragweed, resin-dot skullcap (Scutellaria resinosa), prairie coneflower, wreath aster (Aster multiflorus), black sampson (Echinacea angustifolia), prairie phlox (Phlox pilosa), prairie clover (Petalostemon purpureum), dotted gayfeather, few-flowered psoralea (Psoralea tenuiflora), Missouri goldenrod (Solidago missouriensis), and many others. On heavily grazed sites western ragweed and annual sunflowers (Helianthus annuus) are abundant.

Tallgrass prairie in the eastern 1/3 of Nebraska, norther Iowa, and east-central Kansas varies in elevation from 1,000 to 2,000 ft. Annual precipitation varies from as low as 23 inches in eastern Nebraska to as much as 35 inches along the eastern edge of the tallgrass prairie. The Sand Hills in western Nebraska, a westward extension of the tallgrass prairie, has precipitation as low as 18 inches per year. Except for the Sand Hills of Nebraska and the Flint Hills of Kansas, most of the soils are medium textured. Soils in the Flint Hills are primarily Lithosols. Topography is gently rolling.

Grasses of the tallgrass prairies are primarily little bluestem, big bluestem, switchgrass, Indiangrass, and prairie dropseed (Sporobolus heterolepis). With these occur Canada wildrye (Elymus canadensis), porcupine grass (Spartina pectinata), and eastern gramagrass (Tripsacum dactyloides). Additional species in the Sand Hills of Nebraska include prairie sandreed and sand bluestem. Important shrubs include western snowberry (Symphoricarpos occidentalis), inland ceanothus (Ceanothus ovatus), lead plant, willow (Salix sp.), gooseberry (Ribes sp.), and prairie rose (Rosa arkansana). A wide variety of forbs occur in tallgrass prairie (Weaver and Clements, 1938; Weaver and Albertson, 1956). Typical genera include Aster, Solidago, Silphium, Helianthus, Astragalus, Baptisia, Callincoe, Phlox, Sisyrinchium, Lithospermum, Viola, Anemone, Tradescantia, Psoralea, Erigeron, Petalostemon, Glycyrrhiza, Echinacea, Liatris, Vernonia, Coreopsis, Bidens, Kuhnia, and Carduus. Some trees grow in the tallgrass prairie. These include American elm (Ullmus americana), hackberry (Celtis occidentalis), eastern red cedar (Juniperus virginiana), bur oak (Quercus macrocarpa), cinquapin oak (Q. muhlenbergii), eastern redbud (Cercis canadensis var. canadensis), bitternut hickory (Carya cordiformis), and roughlead dogwood (Cornus drummondii) (Smith and Owensby, 1972).

Tallgrass prairie and forest combinations extend eastward into eastern Kansas, northwestern Missouri, southern Iowa, and Illinois. The tallgrass species are the same as for the tallgrass prairie and the forest is Oak-Hickory (Quercus - Carya). Precipitation increases to as much as 40 inches per year and elevation drops to 500 ft.

Fire Effects--Shortgrass and Mixed Grass Prairie

No prescribed fires have been conducted in these plant communities in the Central Great Plains. The only references are those for wildfires by Hopkins et al (1948) and Launchbaugh (1964). These references were referred to earlier in the southern Great Plains section to compare the effects of fires during drouth years vs. wet years, when prescribed burning might be recommended. Following dry years, Hopkins et al (1948) found that the cover and yield of big bluestem, little bluestem, hairy grama (Bouteloua hirsuta), sideoats grama, buffalo-grass, hairy sporobolus (Sporobolus pilosus), and blue grama were reduced by fire and undesirable broadleaved plants, principally western ragweed increased. Similarly Launchbaugh (1964) found that buffalograss, blue grama, and western wheatgrass did not fully recover after fire until the third growing season.

Based on the data during wet years in the southern Great Plains there does not seem to be any benefit in burning the shortgrass prairie, unless there are unusual litter accumulations. So, it is difficult to justify research for prescribed burning in the essentially shrubless short grass prairie of the Central Great Plains. Most of the mixed prairie is plowed and planted to wheat, so again there is very little need for prescribed burning research.

Eastern red cedar (*Juniperus virginiana*) and western snowberry will invade a prairie protected from fire (Penfound, 1964). American elm (*Ulmus americana*) seedlings establish easily after a burn (McMurphy and Anderson, 1965). However, a later fire will remove the seedlings.

Seed Yields

Several articles (Burton, 1944; Curtis and partch, 1950; Kucera and Ehrenreich, 1962; Old, 1969) show that herbage removal or burning increases flower stalk production. Burton (1944) reported an increase in seed yield in burned areas, grazed, and mowed prairie compared with ungrazed, unburned areas. Curtis and Partch (1950) working in Wisconsin reported a 6-fold increase in flowering on clear-cut sites when compared to unburned areas, and this increase was equivalent to that on recorded burned areas. Kucera and Ehrenreich (1962) also found that flower stalks were more numerous on burned areas. The main species affected were big bluestem, little bluestem, and Indiangrass. Quadrat counts in 1960 showed percentage increases due to burning of 270, 1,200, and 400 respectively.

A detailed study of the effect of litter and burning on flower stalk production was conducted by Old (1969). Flowering on clipped and raked areas was 50% lower than on a current year's burn. This data indicates that in addition to litter, removal of competition by cool season plants, and increased soil temperatures after fire stimulated nitrification which increased seed yields. The addition of ash had no affect, but adding 200 lb/acre of nitrogen significantly increased seed yields over the burn. Below is a tabulation showing the effect of burning and various litter treatments on flowering:

<u>Treatment</u>	<u>Number of Flower Stalks</u>	
	<u>1967</u>	<u>1968</u>
1st year after burning	102	74
Clear-cut	66	63
Cut and left	29	52
Undisturbed	11	34

Litter

Prairie closed to both grazing and fire soon begins to deteriorate (Anderson et al, 1970). Accumulation of mulch depresses herbage yield and reduces the number of plant species (Weaver and Tomanek, 1951; Ehrenreich, 1959). Most of this decrease is associated with lower soil temperatures (Peet et al, 1976).

Reduced herbage yield, as litter increases, is partially related to the amount of ammonium nitrogen. Rice and Pancholy (1973) found that the amount of ammonium nitrogen was lowest in the first successional stage, intermediate in the intermediate successional stage, and highest in the climax. The amount of nitrate was highest in the first successional stage, intermediate in the intermediate successional stage, and lowest in the climax. This data indicates that the nitrifiers are inhibited in the climax stage so that ammonium nitrogen is not oxidized to nitrate as readily in the climax as in the successional stages.

Northern Great Plains

Distribution, Climate, Soils and Vegetation

The Northern Great Plains include the eastern 2/3 of Montana, eastern 1/3 of Wyoming, North Dakota, South Dakota, and the western edge of Minnesota. A large part of Minnesota, however, is a mixture of grassland and forest communities. There are no shortgrass associations, only mixed prairie and tallgrass prairie. The mixed prairie includes eastern Montana, eastern Wyoming, and all but the eastern edges of North Dakota and South Dakota. Precipitation varies from 10 to 20 inches, with the driest areas being on the western edge of the mixed prairie. Soil textures are primarily sand, sandy loam, silt loam, silty clay loam, and loam. Elevation varies from 1,300 to 4,100 ft. The highest elevations occur in eastern Wyoming and southeastern Montana. From this high rolling topography elevation drops to 3,000 ft in northern Montana and then to 1,300 ft in eastern South Dakota and North Dakota. Topography in northern Montana and the central Dakotas is level to gently rolling.

Grasses in eastern Montana and Wyoming are mainly blue grama, needle-and-thread, green needlegrass, western wheatgrass, bearded wheatgrass (Agropyron dasystachyum), threadleaf sedge (Carex filifolia), Sandberg's bluegrass (Poa secunda), plains muhly (Muhlenbergia cuspidata), and junegrass with occasional amounts of little bluestem and prairie sandreed. In the foothills of central and southern Montana rough fescue (Festuca scabrella) will also be a principal dominant. Forbs are not very abundant, but pussytoes (Arenaria spp.), prairie phlox (Phlox pilosa), little club moss (Selaginella densa), scarlet globe-mallow, black sampson, and silverleaf psoralea (Psoralea argophylla) are representative species. Shrubs are predominantly fringed sagebrush (Artemisia frigida), herbaceous sage, nuttall's saltbush, winterfat (Eurotia lanata), and plains pricklypear.

In western North Dakota and South Dakota the grass species are very similar to eastern Montana and Wyoming with perhaps more little bluestem, some green needlegrass, and the addition of western porcupinegrass (Stipa spartea var. curtiseta). Other species present are Pennsylvania sedge (Carex pennsylvanica), Carex eleocharis, prairie dropseed, red threeawn, sand bluestem, big bluestem, prairie sandreed, and sleepygrass (Stipa robusta). A variety of forbs can occur. Major forb species include Astragalus sp., heath aster, aromatic aster (A. oblongifolius), Missouri goldenrod, woolly plantain, Penstemon sp., few-flowered psoralea, hairy golden-aster (Chrysopsis villosa), Phlox sp., little club moss, wild lettuce (Lactuca pulchella), western yarrow (Achillea millefolium), plains erysimum (Eysimum capitatum), scarlet gaura (Gaura coccinea), white milkwort (Polygala alba), herbaceous sage (Artemisia glauca), and dotted gayfeather. Dominant invaders include summer cypress (Kochia scoparia), yellow sweetclover (Melilotus officinalis), gumweed (Grindelia squarrosa), foxtail barley (Hordeum jubatum), and cheatgrass (Bromus tectorum). A number of shrubs are present, which include fringed sagebrush, western snowberry, russet buffaloberry (Sheperdia canadensis), rose, nuttall's saltbush (Atriplex nuttallii), herbaceous sage, plains prickly pear, yucca (Yucca glauca), perennial broomweed, fourwing saltbush, lead plant, willow, and wild plum (Prunus besseyi).

Tallgrasses occupy the eastern edges of North Dakota and South Dakota and the western edge of Minnesota. Surface soil textures are primarily loam, silt loam, and silty clay loam. Elevation varies from 800 to 1,800 ft, and topography varies from a level to gently rolling glacial plain. Precipitation varies from

19 inches in northeastern North Dakota to 30 inches in south-central Minnesota. Grasses are very similar to those mentioned for the tallgrass prairie in the Central Great Plains with a few exceptions. Cool season grasses such as porcupine grass, bearded wheatgrass, quackgrass (A. repens), slender wheatgrass (A. trachycaulum), smooth brome (Bromus inermis), and Kentucky bluegrass (Poa pratensis), are more abundant as codominants with the bluestems, switchgrass, prairie cordgrass, and Indiangrass. Note that quackgrass, smooth brome, and Kentucky bluegrass are introduced species. The shrubs, silverberry (Elaeagnus argentea) and fringed sagebrush, can be added to western snowberry, prairie rose, and smoothleaf sumac. Forbs are very similar to those mentioned for the Central Great Plains. Much of Minnesota is a mixture of grassland and forests, but the grassland species are very similar to those already mentioned for the tallgrass prairie.

Fire Effects--Mixed Prairie

The only fire research that has been done in the mixed prairie of the northern Great Plains is that of Dix (1960) in western North Dakota, and of Gartner and Thompson (1972) in the forest-grass ecotone of the Black Hills. Dix (1960) found that a spring burn reduced herbage yields about 50% after one growing season, but that total yields had fully recovered within 4 years after a late fall burn. A late summer burn (August) was not quite fully recovered after 5 years. With a predominance of cool season grasses, a slower recovery than that for warm season grasses could easily be anticipated based on research for cool season grasses in the sagebrush-grass region (Wright and Britton, 1976).

Dix (1960) found that spring burning reduced the frequency of bearded wheatgrass, blue grama, prairie sandreed, needle-and-thread, and green needlegrass. For western wheatgrass, Carex eleocharis, threadleaf sedge, Pennsylvania sedge, junegrass, and muhlenbergia the frequency remained the same or higher. However, this does not mean that herbage yield wasn't reduced for several years as it very well might have been. Fringed sage, Arkansas rose, and silverleaf psoralea had significantly reduced frequencies, whereas most forbs remained unchanged.

The longer term data (4 years) following a fall burn showed relatively few changes in composition except for a possible reduction in threadleaf sedge, fringed sagebrush, leafy spurge (Euphorbia esula), and little club moss. Hemeoma hispida, stickseed (Lappula redowski), and herbaceous sage increased. The late summer fire also showed that Pennsylvania sedge, prairie sandreed, hairy golden aster (Chrysopsis villosa), and wild lettuce had been harmed by fire but no explanation was given. Possibly, this was still a very active growing season for these species.

This research indicates that there are no benefits to be derived by burning the herbaceous species in the mixed prairie of the northern Great Plains where cool season grasses dominate. On the other hand, fire is capable of killing silver sagebrush (Artemisia cana) (Rowe, 1969), fringed sagebrush, and little club moss (Dix, 1960). However, to get rid of the shrubs a manager will have to allow 3 to 5 years for full recovery of the range. This may be a high price to pay for control of shrubs except in very special situations.

In the forest-grass ecotone of the Black Hills, Gartner and Thompson (1972) did not give plant yield data after burning, but species composition (percent by weight) did not differ significantly between the burned and unburned pasture. Little bluestem and big bluestem made up 82 to 85% of the total forage yield. Based on research from other areas, these species are probably not harmed by fire and could easily be burned during years with normal to above normal precipitation to control scrubby ponderosa pine trees or undesirable shrubs.

Fire Effects--True Prairie

One of the most classic stories about the effect of fire on tallgrass prairie is the Curtis Prairie in Wisconsin which was rejuvenated with fire (Curtis and Partch, 1948; Anderson, 1972). This particular area was abandoned from cultivation in 1932. By 1936 the principal perennials were quackgrass, Kentucky bluegrass, and Canada bluegrass (Poa compressa) (Curtis and Partch, 1948). Various annuals were also present. A number of prairie forbs and grasses were transplanted into the area in 1936 and 1937 at a density of 2.6 plants per 100 ft². It was soon evident that the species were not spreading or holding their own against the bluegrass sod. So fire was introduced experimentally to test the desirability of burning, and to determine the best season and frequency of burning. Since 1950, 1/3 to 2/3 of the 20-acre prairie has been burned every year.

Annual burning between 1941 and 1946 reduced bluegrass sod 80% and permitted big bluestem, rattlesnake master (Eryngium yuccifolium), goldenrod (Solidago rigida), tall gayfeather (Liatris aspera), ragweed (Ambrosia artemisiifolia), white heath aster, and erigeron (Erigeron annua) to increase. Atlantic wildindigo (Baptisia leucantha) showed no effect from fire and purple coneflower (Echinacea purpurea) was the only species reduced by fire. A more recent composition of the prairie from Cottam and Wilson (1966) is shown in Table 3. Note the increases in big bluestem, little bluestem, Indiangrass, Solidago sp., Eryngium sp., Lactuca sp., tall gayfeather, Ratibida sp., and Silphium sp. Quackgrass and Kentucky bluegrass were still declining as of 1961. Wild parsnip (Pastinaca sativa), a troublesome weedy species, is also declining (Anderson, 1972).

In eastern North Dakota, Hadley (1970) also showed an increase in big bluestem and little bluestem, and a decrease in Kentucky bluegrass following spring burning as did Anderson (1972). Other species that increased were prairie dropseed, prairie cordgrass, saltgrass (Distichlis stricta), western snowberry, and Arkansas rose. Wheatgrasses increased on upland sites but declined on lowland sites. Those species that declined were porcupinegrass, needle-and-thread, Poa sp., Muhlenbergia sp., foxtail barley, prairie clover, and heath aster. All of this data was based on yields taken in 1966, a drier than normal year (Hadley, 1970). Total herbage yield was 2,980 lb/acre on the unburned plot and 3,833 lb/acre on the burned plot.

Total production of herbage on the Curtis Prairie in Wisconsin 1 year after burning was 8,478 lb/acre compared to 4,180 on the unburned site (Anderson, 1972). Similar differences for the same prairie have been shown by Peet et al (1975). Removal of litter, increased soil temperatures, and light in early spring were the main factors attributed to the increased plant growth (Peet et al, 1975).

In eastern South Dakota Kirsch and Kruse (1972) have conducted various burns to improve wildlife habitat. One year after burning the increasers (based on plant cover) were big bluestem, little bluestem, prairie sandreed, blue grama, Leiberg panicum (Panicum leibergii), needle-and-thread, porcupinegrass, and needlegrass. Slender wheatgrass, smooth brome (Bromus inermis), and prairie cordgrass decreased. Grasses remaining unchanged were quackgrass, bearded wheatgrass, junegrass, and Kentucky bluegrass. Most forbs increased or remained unchanged. Only Canada thistle (Cirsium canadensis), and rushes (Juncas sp.) declined. Cover of shrubs and half-shrubs remained unchanged.

Vogl (1967) found scrub oak (Quercus ellipoidalis) very abundant in Wisconsin prairies that had been protected from fire for 25 to 80 years.

Table 3. Frequency of Plant Species in Curtis Prairie, Stand A, 1951 and 1961^{1/}

	Frequency	
	1951	1961
Prairie Species		
<i>Achillea millefolium</i>	44	55
<i>Ambrosia artemisiifolia</i>	79	53
<i>Andropogon gerardi</i>	6	44
<i>Andropogon scoparius</i>	--	47
<i>Asclepias verticillata</i>	59	61
<i>Eryngium yuccifolium</i>	1	69
<i>Helianthus grosseserratus</i>	--	5
<i>Lactuca canadensis</i>	48	84
<i>Liatris aspera</i>	2	37
<i>Monarda fistulosa</i>	53	73
<i>Ratibida pinnata</i>	6	32
<i>Rudbeckia hirta</i>	--	3
<i>Silphium terebinthinaceum</i>	2	21
<i>Solidago gigantea</i>	--	3
<i>Solidago nemoralis</i>	--	31
<i>Solidago rigida</i>	--	8
<i>Sorghastrum nutans</i>	--	68
Other Species		
<i>Agrostis alba</i>	--	8
<i>Aster pilosus</i>	71	31
<i>Pastinaca sativa</i>	32	11
<i>Poa compressa</i>	79	97
<i>Solidago altissima</i>	32	48
Weeds		
<i>Agropyron repens</i>	29	11
<i>Oxalis stricta</i>	54	44
<i>Poa pratensis</i>	60	13
<i>Tritolium repens</i>	74	43

^{1/} Data of Cottam and Wilson 1966.

Canadian Great Plains

The Great Plains extend about 250 miles into southeastern Alberta, southern Saskatchewan, and the southern tip of Manitoba. Except for the eastern edge, it is mixed prairie and bounded on the north by aspen (Populus tremuloides) parkland which varies in width (north to south) from 50 to 175 miles. Topography is gently rolling to level and varies in elevation from 3,500 ft in south-central Alberta down to 800 ft in southern Manitoba. Precipitation varies from 10 to 20 inches, increasing as you go northward or eastward. Soil textures are loam, silt loam, and silty clay loam.

Changes in vegetation vary primarily from north to south as you go from the Brown soil zone through the Dark Brown soil zone to the Black soil zone (Rowe, 1972; Nester and Peters, 1977). The Brown and Dark Brown soil zones contain the same grasses as mentioned for the mixed prairie in eastern Montana except for the addition of western porcupinegrass and rough fescue in the Dark Brown soil zone. Shrubs are primarily western snowberry, fringed sagebrush, winterfat, nuttall's saltbush, rose, and silverberry. Forbs are not very abundant, but prairie phlox (Phlox hoodii) and little club moss are the most common.

The aspen parkland is a mosaic of aspen and mixed prairie. The dominant grass is rough fescue.

Fire Effects

In the mixed prairie of southern Alberta, spring burning reduced forage production by 50% the first year, 15% the second year, with recovery completed by the third year (Clarke et al, 1943). The reduction in yields following burning were greater on vegetation of the "Agropyron-type" than on communities dominated by blue grama and needle-and-thread (Stipa comata). Effects of fall burning were less obvious. Production was reduced by 30% the first year with recovery complete by the end of the second year.

Bailey and Anderson (1978) found that the effect of fire on a rough fescue-western porcupinegrass community is complex and cannot be considered simply detrimental or beneficial. Total herbage yields following spring or fall burns remained the same as the unburned control (1,050 to 1,215 lb/acre). However, there were significant changes in plant composition.

Following spring burning, Bailey and Anderson (1978) found a reduction in plant cover for rough fescue, hooker's oatgrass (Helictotrichon hookeri), and sedge (Carex sp.), but no change in cover for western porcupinegrass, slender wheatgrass, or bearded wheatgrass. It took 3 years for rough fescue to recover. Parry oatgrass (Danthonia parryi) and timothy (Phleum pratense) are also harmed by spring fires (Bailey, 1978). Perennial forbs more than doubled, particularly milk vetch (Astragalus sp.), three-flowered avens (Geum triflorum), western yarrow, and blue bur (Lappula redowski). In another study by Anderson and Bailey (1978) they found that vetch (Vicia and Lathyrus sp.), woundwort (Stachys palustius var. pilosa), and bedstraw also increased 1 year after burning. Following fall burning, Bailey and Anderson (1978) found that fire was less damaging to rough fescue but somewhat harmful to western porcupinegrass. Hooker's oatgrass was severely harmed as well as both wheatgrasses. Forbs responded to fall burning similarly as they did to spring burning.

Shrubs responded the same to fire whether they were burned in the spring or fall (Bailey and Anderson, 1978). Silverberry and fringed sagebrush were seriously harmed. Rose and western snowberry were moderately harmed (Anderson and Bailey, 1978; Bailey and Anderson, 1978). Herbaceous sage and raspberry (Rubus strigosus) increased dramatically.

Annual early spring burning in one area of central Alberta has been conducted over the past 25 to 30 years (Bailey, 1978). Preliminary results show that the percent frequency of all shrubs--silverberry, rose, aspen, serviceberry, and chokecherry--is higher on the burned than unburned plots. Frequency of western snowberry remained the same and only Rosa acicularis decreased. However, cover of all shrubs, except for herbaceous sage, was reduced 83% by annual burning. The high frequency but low cover of shrubs seems to be indicative of a fire environment for tenacious shrubs.

Grasses and forbs that increased under the longterm burning program included prairie sandreed, sedge (Carex obtusata, C. heliophila), Missouri goldenrod, bushpea (Thermopsis rhombifolia), western yarrow, and bedstraw. Rough fescue and western porcupinegrass decreased.

Based on what is presently known, fire has potential in the grasslands of Canada to remove litter buildups on ungrazed fescue grassland and to control shrubs with only moderate damage to the grasses. Forage losses can be minimized by using fire only during those springs that are preceded by above normal precipitation. The desired interval for use of fire to control shrubs is probably 5 to 10 years. More use of these ranges by sheep and game in combination with burning may enhance the healthiness of these grasslands.

Beneficial Effects of Fire in Prairie Grasslands

Where it is applicable, the major benefits of prescribed fire in grasslands are control of undesirable shrubs, increased herbage yields, increased utilization of coarse grasses, increased availability of forage, improved wildlife habitat (more food with unburned patches for cover), and control of cool season species where warm season grasses are dominant (Wright, 1974). Several of these objectives can be achieved simultaneously with one burn, which is the advantage of using fire as a management tool.

When large amounts of litter accumulate in a grassland and cause plant growth to stagnate, fire is a very effective tool in the tallgrass and southern mixed prairie grasslands to reduce litter and raise soil temperatures and increase plant growth (Weaver and Rowland, 1952; Kucera and Ehrenreich, 1962; Peet et al, 1975; Sharrow and Wright, 1977). Removal of the litter permits soil temperatures to rise 10 to 30°F in early spring (Peet et al, 1975), which stimulates nitrification by bacteria (Sharrow and Wright, 1977). The high populations of bacteria after fire (Neuenschwander, 1976) break down organic matter in the soil, produce additional nitrates, and this sequence of events along with optimum growing temperatures created by the bare soil when moisture is adequate allow warm season plants to grow at an optimum rate (Sharrow and Wright, 1977). Thus, most of the fertilizing effect from fire in grasslands comes from nitrates that are released following the consumption of organic matter by bacteria after the fire, not the addition of nutrients in ash (Old, 1969; Sharrow and Wright, 1977).

The young, tender growth after fire is naturally more palatable and easily accessible to livestock and wildlife. This enables us to use fire as a very

effective tool to attract livestock to grasses that are normally too coarse and contain too much litter to be palatable. Undesirable cool season grasses and forbs can be reduced with spring burns. Forbs that provide an important food source for many upland game birds are frequently more easily available on burned areas. Resprouts of shrubs are not only more accessible but may be more nutritious up to 3 years after the burn.

Controlling shrubs in the southern mixed prairie, tallgrass prairie, and aspen parkland is a major objective that can be achieved by the use of fire. In Texas we have shown that fire can be used to top-kill mesquite, completely kill 25% of the mesquite on upland sites, kill 50 to 80% of all cactus species, and kill ashe juniper (Britton and Wright, 1971; Wink and Wright, 1973; Wright et al, 1976; Bunting and Wright, 1978). Bragg and Hulbert (1976) have shown conclusive evidence that the tallgrass prairie is easily invaded by shrubs and trees without fire. Preliminary findings on an area burned for 30 consecutive years in Alberta, Canada indicate that fire can be used to reduce cover of shrubs (Bailey, 1978).

In the shortgrass prairie and northern mixed prairie fire does not appear to have any major benefits, except for the few special situations noted in this paper.

Potential Impacts of Fire in Prairie Grasslands

Detrimental effects of fire are generally associated with its misapplication. For example, if we burn during drouth years, we will serously harm the desirable herbaceous species and have less than normal herbage yields for at least 2 years. This is especially true in the shortgrass and mixed prairies. As one moves to the northern Great Plains, more cool season species such as Stipa sp. and Agropyron sp. are encountered and these species may be harmed for 2 to 5 years, depending on when they are burned.

Nevertheless, dry years are often best for long-term effectiveness in killing some shrubs when amounts of fine fuel are minimal. Juniper species are a good example. In these cases fire may be needed only every 20 to 30 years and burning during drouths can be tolerated if the pastures can be rested until the herbaceous species are fully recovered.

Erosion following fires is not likely to be a serious problem unless the slopes are over 20% (Wright et al, 1976) or the soils are sandy. Sandy soils blow easily after being burned. If burning is considered desirable on such soils, low intensity fires should probably be used so that some of the area would remain unburned and a mosaic of burned-unburned areas results.

Improper smoke management can have serious impacts on populated areas. Burning should be done when we have a steep adiabatic lapse rate (day time) and the smoke will rise and disperse at high altitudes. Winds should always be blowing away from nearby towns. Night-time burning is particularly undesirable because the smoke will drift and settle in low-lying valleys and stay there until the middle of the next day. This can lead to complaints to pollution boards and further restrictions on burning. We shold avoid such incidents by burning within a state's prescribed burning regulations and get the area burned in as short a time as possible. Most people are very tolerant of smoke for a few hours, but not for several days.

Frequency of fire can also be a problem. It appears that we should not use fire more frequently than every 5 to 10 years in the western and central portion of the Great Plains. Long-term declines in production of grasses resulting from too frequent burning have been documented (unpublished research by Wright and Bailey). As one goes eastward where the precipitation increases, fire frequency may be every 1 to 3 years without harming the grasses (Anderson et al, 1970).

Management Implications

Shortgrass Prairie

Few uses can be found for fire in the shortgrass prairie. First of all, the grasses do not benefit from fire. They tolerate fire with no loss in forage during wet years (Trlica and Schuster, 1969; Heirman and Wright, 1973; Wright, 1974), but are moderately to severely harmed for 2 to 3 years when precipitation is below normal (Hopkins et al, 1948; Launchbaugh, 1964; Dwyer and Pieper, 1967). Nevertheless, prescribed burns can be used to clean up chained debris and kill pricklypear and other *Opuntia* species less than 1-1/2 feet tall (Heirman and Wright, 1973). In eastern New Mexico prescribed fires can be used to control small juniper trees (Dwyer and Pieper, 1967). Fire also can be used on sand shinnery oak ranges that are in good condition to increase herbage production (McIlvain and Armstrong, 1968).

Mixed Prairie

Central and Southern Great Plains

Prescribed fire has a wide variety of uses in the mixed prairie. It is especially useful, in the southern and central mixed prairie to increase production and palatability of coarse grasses such as tobosagrass and little bluestem that have a tendency to accumulate litter. Most grasses tolerate fire well during normal to wet years, except for sideoats grama and Texas wintergrass (Wright, 1974). Cool season annuals such as little barley and Carolina canarygrass are severely harmed. Spring fires also kill many undesirable forbs--e.g., annual broomweed--and cool season annuals which minimizes competition for the warm season perennials. Thus, if soil moisture is adequate, the warmer soil and increased nitrates with reduced competition from "weeds" provides an ideal environment for growth of warm season grasses. Fire can be used in the southern mixed prairie on a 5- to 8-year frequency (Sharrow and Wright, 1977).

Fire is also effective for burning down dead honey mesquite stems (Britton and Wright, 1971) and killing some honey mesquite trees (Wright et al, 1976). Green honey mesquite trees are difficult to kill. Young honey mesquite trees that were burned at temperatures from 260 to 600°C were easily killed by fire up to 1.5 years of age, severely harmed at 2.5 years of age, and very tolerant of fire after 3.5 years of age (Wright et al, 1976).

Other uses for fire in the mixed prairie are to kill 50 to 80% cactus (*Opuntia* sp.) (Bunting and Wright, 1978), clean up chained debris (Wright, 1972), remove dead piles of ashe juniper and kill young ashe juniper trees (Wink and Wright, 1973), remove brush to ease handling of livestock, and in some cases improve wildlife habitat.

Generally pastures should be burned on a manageable unit basis, except when tobosagrass is dominant. About 1/5 to 1/8 of each tobosagrass pasture should be burned each year (burn new areas on a rotational basis within each pasture), and the cattle need to be on the burn within 2 to 3 weeks after the fire. They graze this species in the spring and fall which takes pressure off the other grasses. Animals will not graze the burned areas in summer and winter. Thus, having burned and unburned areas in tobosagrass pastures is desirable.

Northern Great Plains

In the northern mixed prairie, information for the arid areas (10 to 16 inches annual precipitation) indicates there may be only a limited place for fire as a management tool. However, fire is capable of killing silver sagebrush, fringed sage, and little club moss. More data is needed on the desired frequency of burning. Prescribed burning should probably be conducted in this region only during wet years. Fall burning appears to have the most promise for not injuring desirable forage species (Clarke et al, 1943).

In the moister areas (16 to 20 inches annual precipitation) of the northern mixed prairie, cool season grasses (except for slender wheatgrass and smooth brome) are more tolerant of fire and the warm season grasses (little bluestem and big bluestem) benefit from burning (Kirsch and Kruse, 1972). Shrubs (e.g., Symphoricarpos sp.) can be set back by fire (Bailey, 1978) and ponderosa pine seedlings can be killed (Gartner and Thompson, 1972).

Periodic prescribed burning can be used in fescue grassland to reduce litter buildup on ungrazed slopes, which aids better cattle distribution. Since shrubs can be only set back by one burn, reburns, periodic heavy grazing, or herbicide treatments are required to keep them in check. The effect of fire on wildlife is unknown. Prescribed burning should probably only be done during cycles of wet years and then only on a 5- to 10-year interval.

Tallgrass Prairie

The primary reasons for burning in the tallgrass prairie are to increase palatability, increase nutritional value of tallgrasses, suppress encroachment of trees and shrubs, and reduce competition from cool season plants. Annual burns do not harm the native warm season species if burned about May 1 (Anderson et al, 1970), but when burned less frequently all of the major tallgrass species--big bluestem, little bluestem, Indiangrass, and switchgrass--increase after burning (Hensel, 1923; Aldous, 1934; Dix and Butler, 1954; Robocker and Miller, 1955; Kucera and Ehrenreich, 1962; Hadley and Kieckhefer, 1963; McMurphy and Anderson, 1965; Hulbert, 1969).

Cool season grasses are severely harmed by spring burning. Many researchers (Hensel, 1923; Ehrenreich, 1959; Hadley and Kieckhefer, 1962; Old, 1969) have found that Kentucky bluegrass decreases 80% or more following a spring burn. Curtis and Partch (1950) found that Canada bluegrass and Kentucky bluegrass were severely damaged by spring burning. Similarly, Canada wild rye and Virginia wild rye (Elymus virginica) (Robocker and Miller, 1955), Japanese brome (Bromus japonicus) (McMurphy and Anderson, 1965), and smooth brome (Old, 1969) are all damaged by fire. Species such as smooth brome which begins growth about mid-May are only inhibited by burning, whereas species such as Kentucky bluegrass are almost eliminated by spring burning because they begin growth in early April (Old, 1969).

Late spring (May 1) burning reduces all forbs (McMurphy and Anderson, 1965), although the composition of forbs is changed relatively little (Anderson, 1965). Kucera (1970) proposes a 3-year interval between burns to maintain dominance of warm season grasses, as well as to retain species diversity typical of the native prairie community.

Woody plants will invade a protected prairie (Kucera, 1960; Penfound, 1964; Vogl, 1967; Blan, 1970; Bragg and Hulbert, 1976). Thus, it only seems reasonable that fire should be an effective tool to control woody plants. Fire research on woody plants has been limited, but it appears that, if properly used, it will control woody plants. Annual burning during May controlled buckbrush (*Symphoricarpos orbiculatus*) in Kansas (McMurphy and Anderson, 1965). Pelton (1953) felt that periodic burning would favor western snowberry (*S. occidentalis*) in Minnesota but that annual burning would harm it. The frequency of fire is important. Burning at 3-year intervals would likely prevent tree establishment and gradually reduce the cover of established shrubs and trees.

THE ROLE AND USE OF FIRE IN THE GREAT PLAINS,
by H. A. Wright, A. W. Bailey, and R. P. Thompson

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